UNIVERSITY of TASMANIA

An Australian smart grid pilot: Governance, implementation, and the utility-prosumer interaction

by

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Statement of Co-authorship

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Dedication

This doctoral manuscript is dedicated to Mr Michael Andrew Patterson, B.A., M.P.A., M.Fin.

Strangely, though we have spent more than half our lives together,

it seems more than that, yet the time was not long at all.

We have lived in many places, but it is where you are that's home.

An Australian Smart Grid Pilot:

Governance, implementation, and the utility-prosumer interaction

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Abbreviations

AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
ANU	Australian National University
ARENA	The Australian Renewable Energy Agency
BCR	Benefit to Cost Ratio
BTxxx	Bruny Trial [participant code number]
CBA	Cost-Benefit Analysis
CEC	Clean Energy Council
CONSORT	CONSumer energy systems providing cost-effective grid suppORT
DER	Distributed Energy Resources
DES	Distributed Energy Storage
DSM	Demand Side Management
DoD	Depth of Discharge (battery, by percentage)
EOI	Expression of Interest
EPS	Emergency Power Supply
EV	Electric Vehicle
Finkel Review	Independent Review into the Future Security of the National Electricity Market
FiT	Feed-in-Tariff
kWh	Kilowatt hours
GW	Gigawatt
GSL	Guaranteed Service Level (policy instruction)
HAZOP	Hazard and operability study

ICT	Information Communication Technology
IEA	International Energy Agency
IoE	Internet of Energy
IoT	Internet of Things
IP	Intellectual Property
IPCC	International Panel on Climate Change
ISGAN	International Smart Grid Action Network
LCOE	Levelized Cost of Electricity
LTS	Large Technical Systems
MLP	Multiple level Perspective
NAC	Network Aware Coordination
NEM	National Energy Market
NG	Network Governance
NGO	Non-government Organisation
NPV	Net Present Value
NSP	Network Support Payments
PV	Photo-Voltaics (solar panels)
PV-BESS	Photo-Voltaic-Battery Energy Storage System
R&D[DD]	Research and Development [Demonstration and Deployment]
Reposit	Reposit Power
RITAM	Risk Integrated Technology Acceptance Model
SG	Smart Grids
SLB	Street Level Bureaucrat
SNM	Strategic Niche Management

STS	Socio-technical System
TN	TasNetworks
TRL	Technology Readiness Level
UNFCCC	United Nations Framework Convention on Climate Change
UPS	Uninterrupted Power Supply
USyd	University of Sydney
UTAS	University of Tasmania
VCR	Value of Customer Reliability
VPP	Virtual Power Plant
WTP	Willingness to Pay

Abstract

The Australian electricity sector risks increasing disruption due to a transition toward decentralisation. Smart batteries are expected to enhance decentralisation by providing privately-owned storage. However, decentralised storage is problematic if implementation is ad-hoc. The management of the two-way flow of electricity and payments between households and utilities is a new, pivotal relationship and the focus of this thesis. During system disruption, how might a transition be encouraged to be accelerated yet be governed in an orderly manner? Further, what pre-conditions enhance the breakthrough of smart batteries into the mainstream? This thesis explores these questions theoretically and through an Australian case study. Two areas of theory are drawn on, specifically; policy implementation and strategic niche management (SNM), from Public Policy Studies, and Science and Technology Studies respectively. The theoretical framework proposes four favourable pre-conditions for the innovative breakthrough of technologies into the mainstream, namely: systems-thinking and an SNM approach; policy implementation at the small-scale; households driving change; and, new entrants or business models adapting to system challenges.

The case study is a 34-household smart-grid pilot which tested the coordination of internet-enabled batteries supporting the local grid on Bruny Island, Australia. The research centres on interviews (86) with householders, installers, policy experts, economic and engineering researchers, within and external to the case study.

Thesis findings include: the central importance of the installers for the successful implementation of smart batteries, suggesting that these actors deserve more policy attention; for the prosumer-utility relationship, technology acceptance is argued to be a product of engagement, agency and trust; household decision-making includes significant non-economic values; and, the observation of SNM-like practices.

Chapter One — Introduction

The relationship between energy consumers and utilities is changing, and this relationship is central to a transitioning energy system. The future of this interaction is negotiable, as consumers become prosumers — both consumers and producers of energy — and specifically, of having the control of privately stored energy for the first time since the full centralisation of the grid. The form of this prosumer-utility relationship, and whether it will be equitable and optimal, is not yet known. This presents a challenge to energy policy researchers working at the innovative edges of research and is a challenge of this thesis. An assumption of this thesis is that smart grids, of some form, are likely to be a significant part of Australia's future electricity system, i.e. there is a transition underway to smart grids. It follows then, that the failure or success of implementing smart grids can be assessed through examining whether the technology is accepted by households or not. Exploring householder interactions with the smart battery technology may indicate the social feasibility of future deployment and acceptance of smart grids. The central objective of this thesis is to answer the following question: '***During a time of disruption within the electricity sector in Australia, how might the transition to smart grids be encouraged and governed in an orderly manner?'***

Transition is about the rate of change, or 'acceleration' of change or adaption. The idea of urgency is important feature of discourses of sustainability and is a well-established concept in relation to climate change governance (Roberts & Geels, 2019). This thesis examines tensions between the desire for accelerated innovation (urgency) and the capacity for a large complex system, such as the electricity sector, to undergo rapid change. As noted by many socio-technical system scholars, large systems have significant inbuilt momentum. Governance of transitions is therefore a slow process, and there is a danger that in the rush to accelerate transitions that governments may create unintended negative consequences.

'Orderly manner' refers to both the theoretical (abstract) and the policy aspects of the thesis. First, the scholarship of collaborative (networked) governance is discussed in detail in Chapter Two. Second, the term 'orderly governance' reflects the challenges in the Australian energy policy landscape and the context the thesis case study is situated within. The concept and the phrase 'orderly governance' is central to an Australian government White Paper on the challenges to effective electricity policy: The *'Independent Review into the Future Security of the National Electricity Market: Blueprint for the Future'* (June, 2017*).* Commonly known as the Finkel Review, the investigation of Australia's electricity system was led by Australia's Chief Scientist and was arguably the most important governmental report into the electricity sector in Australia during the period of formulating and writing the thesis. The Review sets out a vision that is closely aligned with a central theme of the thesis — that a transition needs to involve consumers more than is currently the case (Australian Government, 2017; De Gabriele, Hopkin, & W., 2017). In order to realise this future vision, an 'orderly transition [and]…governance' was recognised (Australian Government, 2017). This 'systems-perspective' incorporates governance and perceives the importance (and the societal risks) associated with an unmanaged, inequitable, ad-hoc transition. This thesis therefore engages closely with the foundational concept of what elements of the electricity sector transition are 'manageable'. The concept of what is perceived as manageable (or not) is a underlying theme of the thesis and is a focus of Chapter Five.

In alignment with the overall background and purpose of the thesis, the centrepiece of the Finkel review is founded on low emissions electricity that addresses Australia's 'energy trilemma.' The low emissions vision represents the coming together of climate policy and energy policy for increasing renewable electricity in the system, and meeting international climate change policy objectives through the Paris Agreement (QIC, 2017; De Gabriele et al, 2017; Australian Government, 2017), whilst crucially, having policies that are technology neutral (CEC, 2017). Fundamentally, the Finkel Review addresses climate policy through energy policy, and this thesis focuses on this aspect as it relates to a sustainable transition within the sector.

In a fundamental extension to the issues above, a growing area of academic research is about climate policy and energy policy and the *question of better understanding how to accelerate innovation towards a sustainable transition* (Geels, Sovacool, Schwanen, & Sorrell, 2017; Roberts & Geels, 2019). The thesis explores energy sector innovation towards a low carbon transition and its governance challenges, through the empirical case of smart grid on Bruny Island, Australia.

However, the theoretical basis of this thesis is not dependent on whether smart grids are one of the energy system transitions in the future, or not. Rather, the theoretical basis is underpinned with the search for answers on the concept of accelerating sustainable transitions through technology and policy, where the technology of smart grids is merely one promising example.

In terms of the positioning of this PhD within a wider industry research project, the theoretical basis was developed by the author of this thesis and without direction by the funding agency, although the Bruny Island case study was pre-determined. The PhD contribution involved working as part of a multi-disciplinary team and having to report to the wider team. This PhD was one of four PhD investigations across the three universities and two industry partners working on the Bruny Island research project. The design of the thesis research questions and the choice of theories to investigate, including the methods, was an endeavour of the author of this thesis, and in that sense the thesis is does not depart from a traditional PhD thesis. However, the thesis was heavily influenced by the empirical case – which could only be Bruny Island, Tasmania. In this way a tension existed between the applied social science nature of the narrowly framed CONSORT pilot and the creative freedom and originality that might otherwise be allowed with a wider choice of empirical case. However, the primary industry-orientated question that the project funder ARENA was interested in - understanding more about the role of prosumers in the changing electricity system - was addressed by the wider research team, and it was not required that this thesis directly contribute to answering this particular research question. The wider CONSORT research question was 'How do Networks and Prosumers combine constructively to meet their needs?' (CONSORT, 2015a, p.4).

Now that the thesis has been situated in an academic perspective, the pilot project is outlined, including the technical, logistic and economic context of the study.

As for introducing the CONSORT pilot, it was described as a 'cutting-edge' Australian project (ARENA, 2018b) that trialled the coordination of internet-enabled residential batteries and how they might support the grid, while also providing a financial benefit to residential electricity consumers. The consumers, the household participants of this study, provide use of the stored energy in their battery as a service payable by the network. The project pilot consisted of five project partners within a specialist interdisciplinary team led by the Australian National University (computer science), and with partners the University of Sydney (grid economics), the University of Tasmania (policy, governance, and sociology); industry partner TasNetworks (the transmission and distribution electricity network); and a software (ICT) new entrant to the energy market, Reposit Power. Physically, the pilot comprised 34 rural households on Bruny Island, South East Tasmania, with rooftop solar and lithium 'smart' (internet-enabled) batteries installed at their homes. The pilot technology acted as a Virtual Power Plant (VPP), which was aimed at enabling the households to optimise their electricity generation and consumption to reduce householder costs while also providing support to the grid. The pilot supported the island's constrained undersea cable at times of peak demand and reduced use of a backup diesel generator. The grid support had three elements: 1) the project partner Reposit Power provided the energy management system (software) to manage the battery system behaviour 2) the project partner ANU tested their Network Aware Coordination (NAC) algorithms that were overlain on the Reposit software — providing individual battery responses rather than all discharging or all charging as per the Reposit software that coordinates the batteries as a fleet, 3) the project partner TasNetworks could manually override and also request support of the batteries when they decided to do so. The ANU NAC algorithm was the unique and distinctive aspect of the pilot, compared to other smart grid pilots and similar investigations operating at the time in Australia (see ARENA, 2015b; Energex, 2017a; Ginninderry, 2017; PositiveCharge, 2018). In addition, CONSORT was unique amongst ARENA-funded projects in that it had a dedicated social science team, rather than comprising only engineers or economists, which is the standard for ARENA projects. This is explored in detail in Chapter Four, and the specifics of participant recruitment and other key elements of the pilot are also described more fully in Chapter Four.

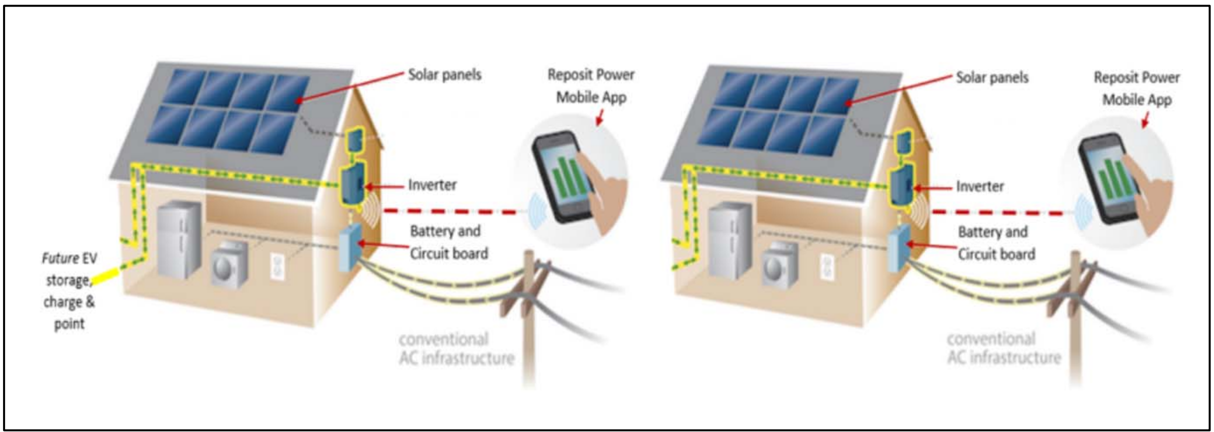


Figure 1.1. Components of a Virtual Power Plant with Reposit Power as an example Energy Management System (stylised design adapted from Rebus http://rebuspower.com)

The context of the pilot and the household participants is discussed further in Chapter Three, while the academic value of the pilot is first outlined here, in Chapter One.

The thesis was directed and prescribed by this CONSORT pilot. CONSORT is a large, significant project investigating the technical, economic, and policy, consumer and social aspects of a potential large-scale social and technical change in society. Deep investigation of the technical and economic aspects of the trial was undertaken by PhD candidates in those areas of specialisation, as would be expected for a technical trial of this nature. It is less common that a deep PhD investigation be undertaken of a predominantly technical trial from a social, policy, governance, and a particularly human perspective. However, these aspects are critical in relation to large-scale technological change in society, and this is one of the research contributions of this thesis.

This thesis is the product of an investigation that sought to uncover concepts and strategies related to accelerating deployment of innovative technologies; and specifically, the investigation was carried out through observing the deployment of ‘smart battery’ systems on a cohort of residential electricity consumers. The theoretical goal here is one that is not merely observing, documenting and providing a novel or controversial way of understanding change. On the contrary, the main theoretical driver is one that focuses on the possibilities for a more managed transition of the electricity sector. Therefore, given the deliberate and purposeful nature of this aim, policy and governance lenses are employed for drawing out key insights about the governance of a sustainable transition. Specifically, the areas of scholarship this thesis contributes to are the strategic management of socio-technical projects (Strategic Niche Management); policy implementation; models of technology acceptance (management); and decision-making typologies that underpin consumer preferences. These two main areas of scholarship — socio-technical systems and policy implementation – used in conjunction are shown to increase understanding of the conditions or pre-cursors for 'real world' upscaling of niche innovations into the mainstream.

Presented from different angles, each chapter of this thesis is about the societal change associated with an emergent innovative technology: residential smart batteries. The investigation therefore centres on aspects of energy policy implementation and governance as it relates to smart grids, and the perspective is infrastructure-centric. Infrastructure, and particularly battery storage, is the empirical focus of the thesis. From here, social interactions with the infrastructure by participants and others and understanding the possibilities of this new relationship are explored.

In summary, this thesis was an analysis of a 'live' smart grid pilot on Bruny Island, Australia, as a way of understanding how a future electricity system may adapt to the increased use of decentralised energy and electricity storage which is owned in by the consumer, rather than by the utility or network. This fundamental shift is interrogated from a management, policy and sociological perspective because it is critical to understand how this radical shift took place, and thus make recommendations about how such transitions might be better supported and governed.

1.1 Background

The policy starting point of this thesis, with its focus on distributed storage, is the context of rapid structural change (transition) within the electricity sector, and the urgency of solving the 'energy trilemma' of cost-effectiveness, grid stability and managing greenhouse gas emissions in the electricity sector. The thesis is positioned centrally to this transition in the sector and seeks ways to understand and better manage the unwieldly complexity and sheer scale of this change. That is, this thesis seeks to increase understanding

The energy trilemma implies storage as the almost self-evident next step in the transition, for example:

> 'Australia has ratified the Paris Agreement on climate change…[and] The Finkel review recognises the pressing need to address the "energy trilemma" [of] security, affordability and sustainability… [requiring a] rapid rollout of…storage…this is not rocket science'

(TEC, 2017).

Additionally, 'numerous major economic studies of climate change mitigation, such as the 2006 Stern Review, have concluded that the cost is lower the sooner action is taken' (Byrne, 2017, p. 3). The United Nations Paris Agreement, with the majority of the world as signatories, calls for accelerated action with respect to a sustainable energy transition (UNFCCC, 2015; UNTC, 2018). A key aspect of the focus on a sustainable transition — from governments, organisations, and researchers - is about smart grids; as a solution for the anticipated impact of grid-connected residential batteries, while addressing energy and climate change policy objectives (AEMO&ENA, 2018; AER, 2016; APVA, 2013; Clastres, 2011; CSIRO, 2014; Eyer & Corey, 2010; Finkel, Moses, Munro, Effeney, & O'Kane, 2017; IEA, 2011; ISGAN, 2017; Lopes, Henggeler Antunes, Janda, Peixoto, & Martins, 2016; Porteous, Godfrey, & Finkel, 2018; Temby et al., 2014; Varaiya, Wu, & Bialek, 2011).

More specifically, a key recommendation from the International Energy Agency's report 'Technology Roadmap Smart Grids' is that the 'development of smart grids is essential if the global community is to achieve shared goals for energy security, economic development and climate change mitigation' (IEA, 2011, p.5). The Australian electricity system appears, however, to be slowly transitioning towards a more economically and environmentally sustainable trajectory, or pathway; and, there are significant barriers — organisational, institutional, technical, infrastructure and social challenges.

It is widely known that the 'energy supply sector is the largest contributor to global greenhouse gas emissions' (IPCC, 2014, Ch 7, p.516) and it is acknowledged that any pathway requires decoupling of economic growth from energy consumption/intensity; and in turn, this requires urgent technological innovation and implementation. One pathway to sustainability within energy systems is demonstrated through implementation of renewable energy based smart grids (Liserre, Sauter, & Hung, 2010, p.19; Varaiya et al., 2011, pp.40,43) and through the monitoring that smart grids allow (Clastres, 2011, p.6). In order to understand this path of technological innovation and implementation for sustainable outcomes in the electricity sector, methods of policy implementation and governance are important to investigate because they can facilitate change in a timely, orderly manner.

The problem tackled by this thesis, and its core empirical investigation, is about understanding how aspects of the prosumers and utility relationship change with the installation of household-level storage, and further how that change can be accelerated and supported. This purpose supports the mounting evidence and argument for *urgency* in response for an accelerating transition within the electricity sector (Geels, Berkhout, & van Vuuren, 2016, p.577; Geels, Sovacool, Schwanen, & Sorrell, 2017; Hakner, 2017; IPCC, 2018; see Chapter Four).

The concept of urgency (acceleration of response) is explored against the tension of management and governance, because successful governance and implementation is often fraught and policy processes are slow (Pressman & Wildavsky, 1973). More widely, large sociotechnical system change is slow and this presents difficulties for governance (Bolton & Foxon, 2015; Geels, 2002; Hughes, 1987).

As part of the academic understanding of the challenge of 'accelerating transition', smart grids are explored as a solution in infrastructure requirements. Smart grids enable solar generation and use to be orchestrated to reduce peak demand, with smart battery storage. By contrast, within Australia's National Energy Market (NEM), electricity generators compete on price in a wholesale market, and issues with current generation and security of supply include that coal and gas generation become inefficient and prone to becoming non-operational at high temperatures. This is a particular problem for the Australian summer conditions when the highest peaks in the NEM occur. Further, 'If rooftop solar did not delay and reduce peaks in this way, more large power stations would need to be built' (Ogge, 2018, p.3). One of the great practical network benefits of residential solar is that it off-sets expensive infrastructure investment (ARENA, 2018a, p.12; Carey, 2018; Dickers, 2016), by 'reducing strain on the grid' (Heymans, Walker, Young, & Fowler, 2014, p.29). Consequently, given the significant potential for residentially owned batteries in Australia, this crucially indicates for the network, and from a systems-perspective, that consumers cannot be taken for granted by utilities. Understanding how householders, as 'prosumers', and utilities will interact in the future is critical to comprehending the possible futures of the electricity system and has both practical and academic legitimacy and importance as a topic of investigation.

Next the CONSORT pilot, the subject of this thesis, is positioned within the context of the Australian energy system.

1.1.1 The CONSORT project within an Australian context

The CONSORT pilot is trialling a smart grid through residential, lithium-based, internet-enabled batteries with Bruny Island participants. It is a large multi-million-dollar research effort, harnessing interdisciplinary capabilities through the industry partner organisations, including PhD candidates in economics and computer science to help solve the pressing problem of how to manage increasing distributed storage into the future. Australia leads the way in this field in a practical sense and so CONSORT is not just a research project, but a pilot with pressing, practical application.

Australia currently leads the world with the biggest market for residential electricity storage (Minnock, 2018), so it is unsurprising that Australia is viewed as the 'preferred testbed' for new storage technologies (Manghani & McCarthy, 2018). It is acknowledged that integrating storage into the grid (and lithium batteries in particular) will be a cornerstone in addressing the energy trilemma, and that Australia is expected to lead the way into the future (Godfrey, Dowling, Forsyth, Grafton, & Wyld, 2017, p.49).

The case study for this thesis; CONSORT, is an Australian smart-battery pilot, and is, and one of 200 ARENA renewable energy based pilots. Ten related Australian mainland pilots are currently underway, though not with a special focus on the residential sector; they are investigating demand response in dealing with mainland summer peak demand events (AEMO, 2017a). In another significant battery trial and deployment, the Government of South Australia is currently implementing what it describes as the 'world's largest virtual power plant' with an initial 1,000 batteries rolled out to public housing properties, and up to 50,000 private homes by mid-2019 (Government of South Australia, 2018). This is a government program implementation and not a research project, however, further afield, in the U.S. state of Arizona, 'one utility in central Arizona is collaborating with the National Renewable Energy Laboratory (NREL) to launch one of the largest battery energy storage (BES) studies to date for up to 4,500 of its customers' (NREL, 2018) with the research running over three years. These examples, including CONSORT, are either research pilots or government trials aimed at the residential energy storage sector. The residential sector has a highly significant impact on the electricity sector transition, and the residential sector responses are the focus of this study. The role of the residential sector is crucial to better understand given the significance of the residential electricity consumption on a global scale, and the CONSORT pilot provides the vehicle in which to thoroughly examine a cohort of newly installed smart-battery systems in the residential sector during the trial period.

Furthermore, given the Australian context, with the rate of residential battery installation tripling every year from 2015 (ARENA, 2018c, p.2), the potential for residential storage to support the grid is undeniable. The Australian Energy Market Operator (AEMO) predicts that distributed energy resources (DER) could provide 15% of Australia's electricity demand (GWh) within 12 years, by 2030 (ARENA, 2018c, p.2). This transformation is coming about very rapidly, and the much of the world is looking to Australia for lessons learnt in how this large-scale transition unfolds (IEEFA, 2018; Stocks, Blakers, & Baldwin, 2019).

A key step in an energy storage revolution driven by the residential sector is demand-side management (DSM). DSM is the ability to manage electricity at the household level, and smart batteries are an integral enabler of this electricity management. The importance of DSM is that it places agency and power in the consumer's hands and has the ability to be harnessed, in aggregate, to reduce peak demand (electricity consumption peaks). Managing growing peak demand is the number one issue facing electricity network operators in Australia. Residential energy consumers with batteries are prosumers who own and store electricity. These prosumers in combination with DSM, and in conjunction with growing decentralisation of the grid, are rapidly modifying the centralised electricity system as we currently understand it. These are the crucial elements of residential electricity sector change studied in this thesis: DSM, growing decentralisation (which enables DSM to flourish) and the role of prosumers (who drive both DSM uptake and decentralisation).

Before moving on to the discussion of demand-side management and prosumers it is important to situate the context of the CONSORT pilot at the outset, with respect to the relationship between prosumers and new energy technologies, and the approach of this thesis. Firstly, due to the nature of VVPs being automated energy management systems, VPP arrangements work to fit around consumer energy behaviours. Therefore, direct load control is not managed via consumer energy behaviour. The VPP outlined in Figure 1 represents an IoT system (i.e. the VPP) and this supersedes issues of having to incentivise consumers to manage energy patterns.

Secondly, it is acknowledged that incentivising behaviour change is less relevant with the emergence of VPPs (IoT systems) but that there remain strong links from behaviour change concepts of *participation*, *involvement* and *engagement* and then also implementation — or technology *acceptance*. The scholars outlined in Chapter Five (see Table 5.1) that investigate energy management systems and prosumers with regard to consumer involvement, engagement and participation include Bigerna et al, (2016); Gangale, (2013) and Abi-Ghanem, (2014).

1.1.2 Demand-side management within a distributed electricity network and the importance of prosumers

This thesis positions power of influence of the residential sector, as potential prosumers as central, critical and pivotal to transition. In terms of underlying drivers of smart grid investigations, determining cost-effectiveness is a key factor, and this relates to demand management. Electricity

Demand Management (DM) is a purposeful intervention by utilities that aims to change consumer energy demand, either by reducing or shifting it. Currently, all consumers pay for unnecessary generation that runs into the hundreds of millions of dollars, and this is reflected in disproportionate electricity bills (Dunstan, Alexander, Morris, Langham, & Jazbec, 2017, p.iii). However, the implementation of demand response remains an emergent, untapped potential and an entirely new conception for electricity markets (ARENA WIRE, 2017).

The 2017 report on storage by the Australian Council of Learned Academies (ACOLA) also highlights the central importance of prosumers in a transitioning grid and the driver of cost; the report cites a survey of residential consumers that reducing bill costs and the cost of the battery system itself are the most significant deciding factors to consumers, even more than safety (Godfrey et al., 2017, p.75).

1.2 Research questions

The network and prosumer relationship is central to future energy systems — and it is not yet known what forms this relationship will take. The CONSORT pilot may be described as a test-bed of how this relationship could work in order to be mutually beneficial to both prosumers and the network. What is known is that the energy system is currently experiencing a structural transformation and that further 'disruption' is inevitable, in large part due to increased decentralisation with small-scale renewable energy resources, specifically residential solar PV (ARENA, 2018c, 2019a; Simhauser & Nelson, 2012; Stocks et al., 2019). An understanding of the opportunities and barriers for policy implementation and governance are important in this climate of change, because they can facilitate the transformation in a fair, safe, orderly manner that is cognisant of a range of possible consequences. In addition, the policy support should also be technology-neutral because in is unknown at this stage whether lithium batteries are the final or 'first best' solution as a technology from a policy perspective; it is too early to tell. Finally, fairness and equity are also important considerations overall. The overall objective for the CONSORT pilot research team was to answer the question: ***'How do Networks and Prosumers combine constructively to meet their needs?'*** (CONSORT project Plan, 2016).

From a theoretical standpoint, the objective of this PhD is to answer or gain insight into the following core research question: 'During a time of disruption within the electricity sector in Australia, how might the transition to smart grids be encouraged and governed in an orderly manner?'

The premise of the PhD study is that smart grids are a significant and emergent part of Australia's transforming future energy system, and that it is critical to explore the prosumer (participant) interactions with the technology, and pricing interventions, to gauge the social and economic feasibility of implementing smart grids. In this thesis the participant-interactions with the technology are investigated. These interactions may indicate future prosumer-technology interactions more widely, and these participant-technology interaction issues include themes of communication, engagement and trust, as well as ease of use, which relate to feasibility of policy implementation of smart grids.

A very brief descriptive outline of the chapter research questions is provided below as a general overview. This outline is tabulated for reference in Table 1.1 (within Section 1.3) and follows with the conclusion of Chapter One which comprises the comprehensive chapter-by-chapter outline that, where appropriate, also justifies the rationale, logic and context of each chapter within the thesis.

In this thesis answers to the following questions are investigated:

The literature review investigates governance and policy implementation scholarship as well as 'socio-technical systems' scholarship which looks at large scale societal changes that involve technical revolutions or major change. By the end of Chapter Two, the literature review, the theoretical framework is established for the question *What are the pre-conditions for innovation to break through to the mainstream?*

Chapter Three is a methodology and methods chapter, and in Chapter Four, the CONSORT pilot was investigated in relation to the concept of Strategic Niche Management (SNM) (as described in the literature review), and how it applies in practice to the CONSORT pilot and the researchers involved.

Chapter Four seeks to answer *How is the CONSORT pilot governed and implemented; and what SNM-like practices and processes were used?*

Chapter Five argues that policy implementation, to be successful, requires acceptance; and so, the question is asked: *What are the conditions that lead to consumer acceptance of a new technology?* Chapter Five focuses on engagement, agency, trust and acceptance. These themes are examined in order to seek answers to how the growth in prosumers and their participation in the energy system can be managed and enhanced. The assumed desire for increased agency in prosumers is also questioned.

In Chapter Seven, in depth social research on cost-benefit analysis (CBA) provides the opportunity to ask *Are PV-battery systems cost-effective?* As well as investigating the CBA methodology as a decision-making tool. The analysis includes non-economic values and decision-making typologies.

In Chapter Six the focus is on the battery-system installers, and this is because they are the interface between the network and the prosumer (participant) and have a large influence on the success, or not, of prosumer acceptance and use of a new technology such as smart batteries. *The paper aims to examine how innovation intermediary roles might adapt post-disruption*. The policy implementation scholarship is explored to understand the installers role in a post-disruption phase. This chapter investigates how regulation or policy might enhance the utility-prosumer relationship.

1.3 Significance of the study

The significance of the thesis is demonstrated by the original contribution that it adds to the scholarly research in the field. These contributions are discussed in depth in the individual empirical chapters and also in the thesis conclusions. They are also briefly summarised here.

This thesis engages with the concepts from sociotechnical transitions (STS) scholarship and public policy; and examines strategic niche management (SNM), situated within the wider body of STS scholarship. SNM can be described as a form of intra- and inter- project management that seeks to implement the pilot outcomes widely, to accelerate deployment to the mainstream. This process relates to the overall aim of supporting innovative, sustainable technologies, in a *managed* way. Given the potential for SNM as a process, SNM-like features were explored within the case study, and from a policy perspective that is generally lacking in other research work to date. SNM is a potential management and policy tool that has been studied in regard to external, historical, retrospective cases of electricity transition, though not on contemporaneous renewable energy research projects. Where SNM scholarship has been applied to live, real-world cases, the niche field is dominated by electric vehicles (Schot & Geels, 2008; Schot, Hoogma, & Elzen, 1994; and Xue, You, Liang, & Liu, 2016). A novel contribution to scholarship here is that the SNM scholarship is applied not historically, but on a contemporaneous (live) smart grid pilot, where it is considered within the project itself as it unfolds and conceptually tested by interviewing the pilot researchers and other external experts. This work, in Chapter Four, also provides a partial project-ethnographic approach, which is an immersive, insiders-view of a renewable energy pilot unfolding. This methodological approach provides insight that other PhD candidates may not have had the scope or freedom to conduct due to access issues and disciplinary boundaries.

The scholarship on policy implementation is far less common than research on policy development. This thesis focuses on the important, less-researched area of policy implementation. Policy implementation is fundamentally well-recognised as pivotal to governmental program success (Pressman & Wildavsky, 1973), and yet remains a difficult and under-researched area of scholarship. Critically, a gap often exists between policy development and policy implementation; or the unintended 'implementation gap' (Olswang & Prelock, 2015, p.1818) and this gap could be perceived as policy failure. This thesis pays special attention to reasons for the implementation gap. Specifically, an original contribution is in re-imagining ways to close the implementation gap through the support and frameworks that could be provided for the installers to facilitate a more orderly transition, through drawing on socio-technical/SNM scholarship.

Hence, the thesis extends the study of policy development in relation to small-scale management (SNM) and the pivotal role played by households and technicians (battery-PV installers) from a socio-technical systems (STS) perspective and a policy implementation perspective. This specific theoretical investigation of SNM and policy implementation represents an original contribution and extends both areas of scholarship.

1.3.1 Thesis Boundaries: Scope of the Project and Limitations

The scope of the thesis and the PhD were constrained by the CONSORT pilot, as a research pilot, because it is an industry-PhD. The theoretical lenses employed are governance, policy, and management as they relate to smart grids, and within smart grids prosumers are a focus.

A number of areas then are considered to be out of scope of the thesis. For example, one area that could easily be a thesis unto itself is the influence of politics. Politics is mentioned throughout where it is relevant, but, has no dedicated chapter. The reason for this is that the thesis formulates concepts about ideal scenarios and conditions for accelerating change, and especially investigated at the micro level. This micro level matches the case study of the pilot, of human behaviour and the interaction with the smart battery technology, and for the understanding of consumer acceptance, and of policy and technology implementation at this small-scale. In addition, from the theoretical perspective, this thesis focused on what is possible to influence; and so, concepts of *management* become important to study. The 'unmanageable' power of politics is acknowledged to be able to either accelerate or hamper transition – but there is not the scope to cover this – and similarly with business and policy entrepreneurs, who are framed, given the case study and for the purpose of the thesis as somewhat 'uncontrollable forces.' Thus, in order to suit the case study, which is 'managed' insofar as it is a controlled socio-technical experiment, the large-scale political influences are not closely engaged with. Therefore, what can be understood to be controllable or manageable through a logical policy and STS lens was a focus. The attention was on the optimistic possibilities rather than the unfruitful, intractable improbabilities from a theoretical perspective.

Research investigations were also initially made into the field known as Transitions Management (TM), and the synergies between the concepts in this field and that of governance, management, and agency which are critical features explored in this thesis. However, it was decided not to continue with TM as a line of enquiry for this thesis. This was decided on the basis of lack of research found within TM that relates the concept of management to the micro scale or project-scale — which is necessarily suited to the scale of the pilot and analysis within this thesis — and this feature of small-scale analysis is also the reason why Strategic Niche Management was focal point of this thesis. It appeared that the established work within TM focused on the various challenges relates to steering *societal-scale* socio-technical system transitions (Meadowcroft, 2009; A. Smith & Stirling, 2008; G. Verbong & Geels, 2007; G. P. J. Verbong & Geels, 2010).

Finally, two other aspects are explained as being carved out from the overall scope. It was necessary to completely by-pass the significant research on large-scale storage and mark this area as out of scope for the thesis; due to the focus on residential systems, which are of course, at a micro-scale. Additionally, besides householder responses and consumer demand that can be related to the case study, there is not an exploration of *collective* social movements because *individual* reactions and decision-making and underlying logics are studied; or alternatively, the network interaction with individuals is studied.

Next, is a summary of the research questions is compiled in Table 1.1, followed by a fuller description of the chapters.

Chapter and title	*Topic covered*	*Research Question*	*Aims*
Chapter One Introduction	Background and chapter outlines.	***During a time of disruption within the electricity sector in Australia, how might the transition to smart grids be encouraged and governed in an orderly manner?'*** Underlying this is '**What are the pre-conditions for innovation to 'break through' to the mainstream?'** Positioning chapter; frames the thesis and outlines chapters ahead. Outlines the context and reason for the pilot.	To provide the contextual framework of the thesis.
Chapter Two The conceptual framework for the research on the CONSORT smart grid pilot	A two-stream approach: 1)STS- Strategic niche management, and, 2) Governance and policy implementation	Chapter two set out the theoretical framework of the thesis by exploring the question set out in Chapter One above.	To link two different fields of scholarship: that is, to cross-pollinate socio-technical systems theory (MLP, SNM) with governance theory and policy implementation.
Chapter Three Methodology and methods	Methodology and methods	Present what methods/methodology have been used and why have these methods were chosen. Justify the appropriateness of methods.	To provide a robust justification for the methodology and methods applied to faithfully answer the research questions of the thesis.

Chapter Four Strategic niche management and governance: An exploration of the CONSORT pilot	Description of the case study, an exploration of SNM-like practices in CONSORT including a partial project ethnographic description.	How is the CONSORT pilot governed and implemented; and what SNM-like practices and processes were used?	Introduction to the case study, and its context as a reflection of the pilot unfolding. This chapter aims to investigate the pilot from the point of view of SNM principles to establish whether SNM was unofficially employed within the pilot.
Chapter Five The precursors of acceptance for a prosumer-led transition to a future smart grid	Householder desire for agency and engagement and indicators of a changing utility-prosumer relationship. Innovation and sustainable transitions underlay this chapter.	What are the conditions that lead to consumer acceptance of a new technology (smart batteries)? Examining acceptance from a network-level perspective, a second question is; How might the enabling conditions be related in a way that may assist utilities and prosumers to accelerate a transition?	This chapter aims to provide a large-scale, network view on transition and implementing/rolling out smart grids. The aim is to explore the tension between the utility and prosumer understanding of what could constitute new levels of agency for the prosumer, and engagement between the parties – as a new relationship.
Chapter Six The evolving role of battery system installers within a transitioning electricity sector	Installer, utility and Prosumer Interviews	The paper examined how innovation intermediary roles might adapt post-disruption. The policy implementation scholarship was explored to understand the installers role in a post-disruption phase.	The aim is to link STS and policy fields of literature. Namely, to explore what innovation intermediaries are in the context of CONSORT and compare with SLBs. To escribe the householder-technology engagement, and to outline prosumer difficulties and learning for rollout.

Chapter Seven Transition to decentralised storage: Consumer decision-making and cost benefit analyses	Cost-benefit analysis of residential battery systems. A social science analysis of CBA as a method, and a critical investigation into CBA suitability for the case study.	The paper centres on the concept of problem typologies (logics) in relation to consumer-decision-making as a key driver towards a sustainable transition. Specifically, the decision-making typology investigated is the cost-benefit analysis methodology. What are the CBA assumptions? Are PV-battery systems cost-effective? The analysis is linked to the complexities, gaps and tensions between householder decision-making 'values' and the gap in utility decision-making 'values.'	The aim is to determine a plausible CBA. This contributes to answering a CONSORT question on the cost-effectiveness of the system from the point of view of the householder. The approach attempts to address a scholarly gap, where no scholarship was found up to 2019 that analyses CBAs and battery storage that applies detailed householder values and assumptions. The aim of the chapter is to provide the prosumer point of view, where upscaling of the niche is "consumer driven" and where cost is important, but where it is not the only factor in decision-making.
Chapter Eight Discussion and Conclusions	An electricity system transition though smart batteries, prosumers and utilities. Final conclusions.	'During a time of disruption within the electricity sector in Australia, how might the transition to smart grids be encouraged to be accelerated and governed in an orderly manner?' Underlying this question is: What are the pre-conditions for innovation to breakthrough to the mainstream? *Theoretical impacts:* 1) A contribution is made to scholarship on STS (roles of intermediaries) by bringing in	CONSORT-specific findings are presented in chapter-by-chapter findings, before a synthesis of cross-cutting themes from the theoretical basis of the thesis. The final conclusions are outlined.

	scholarship on policy implementation (roles of SLBs): resulting in a novel theory of the evolution of intermediaries as socio-technical systems mature. 2) A contribution is made to the scholarship on MLP— specifically a finer-scale understanding of the conditions required for MLP innovative 'upscaling.' *Practical outputs:* A contribution is made to an understanding of how policy might support innovative sustainable technologies at the small, householder scale – specifically measured by providing policy learnings, particularly for the papers in Chapter Five and Chapter Six.
Appendices	Appendix A —Fieldwork and Ethics H0016022 and amendment, final report, consent form, information sheet and indicative question sheets. Appendix B — Candidature outputs, presentations, publications and PhD contribution to ARENA Milestone Reports

Table 1.1. Thesis Research Questions

1.3.2 Outline of Chapters

This section briefly outlines the content and contribution of the chapters in this thesis as indicated by the table above, and this acts as an overall guide to the flow, linking and logic of the chapters.

As a result of a thesis incorporating publications format, additional consideration has been given to the structure of the thesis where the submission and possible publication of empirical chapters are included. Given that a paper necessarily comprises a stand-alone work with regard to the research questions, approach, theoretical background and scholarly contribution — this implies that each paper required additional theoretic work to be done. The challenge with this process was not just of some necessary repetition, due to providing background and context for the papers, but also the challenge to the structure and flow of the thesis. In order to address this and to provide a strong theoretical linking of the papers together, this thesis provides a lead-in to each empirical chapter (whether submitted as a paper or as a standard chapter), as a 'linking-one-pager' that encapsulates the context, contribution and link of the work to the theoretical basis of the thesis overall. These context-setting one-pagers assist in sign-posting and maintaining the structure and flow of the empirical chapters in relation to the theoretical framework of the thesis.

In terms of summarising the process of the publication route taken, it can be described as follows: once the papers were drafted and reviewed by the supervisory team, the drafts then went through an iterative process of review, guidance and input with a focus on the co-authors. The co-authors were Ph.D. supervisory team members with particular expertise and knowledge closely matched to the paper's content. Different journals to were chosen to submit to, and these were considered to be the most suitable to the papers, and so consequently the content and approach of the papers is distinctive. In addition, the tone and style of the papers are also different, and this reflects the collaborative nature, learning and compromises which occur as part of the co-authorship submission, and publication route chosen for this thesis.

Chapter Two — Literature Review

The theoretical basis of the thesis draws from two quite separate streams of scholarship that best theoretically underpin the PhD case study. The two-stream theoretical approach assists in cross-pollinating ideas and increasing an understanding of what is possible in terms of innovative technologies, and, by extension a large-scale sustainable transition.

The first stream is a STS perspective. This provides a context for the thesis in terms of introducing the energy system, infrastructure and system transition. A systems-thinking approach borrowed from Hughes (1983) to transformation is outlined as a holistic approach to large-scale system change. The most commonly employed STS framework, known as the Multiple-Level Perspective (MLP) is described, and forms the taxonomic framework of the thesis by describing small-scale innovations that 'break through' into mainstream adoption. The MLP framework contextualises the smart grid pilot as a small-scale niche pilot. From this context, strategic niche management (SNM) is employed, specifically because this thesis is concerned with agency and possibilities for influencing change, which SNM allows. SNM is contrasted against the system-thinking approach, because SNM is notably a small-scale 'management' influence. SNM theory is articulated, allowing it to be revisited in Chapter Four where the SNM principles are tested within the live pilot setting.

The second theoretical stream is a network governance and policy implementation perspective. This perspective is employed because it sheds light on understanding how technological innovations might be implemented and governed in the real world. This section begins by describing the theories of governance that show potential for supporting sustainable innovative technologies, and highlights theories that could generate learnings that could contribute to improved future policy implementation especially as it applies to the small-scale (such as understanding householders and installers). Policy implementation in this section focuses on the micro-scale 'specific behaviour that at the lowest level of the implementation process that generates the need for a policy' (Elmore, 1979, p.604). Also, within the policy implementation scholarship is social acceptance and engagement, concepts which are tested in Chapter Seven in relation to householder engagement, agency, trust and acceptance. These themes contribute to the thesis overall as one sequence of influences towards upscaling of innovative technologies through consumer preferences and decision-making.

This thesis employs socio-technical systems theory in order to pinpoint the pre-existing conditions necessary for 'break through' of innovative technologies to mainstream deployment. The scholarship on STS and policy implementation, as well as government reports on the Australian energy sector transition, brought to light four pre-conditions that appeared to support up-scaling. These four pre-conditions are elaborated on in Chapter Two, however, briefly they are 1) Applying SNM for transition (management and a systems-approach to change); 2) Applying network governance and policy implementation strategies for transition; 3) Consumer preferences driving change; and 4) New entrants to the energy system that drive transition.

Chapter Three — Methods and Methodology

This chapter justifies the choices of methods used in gathering evidence, as well as providing the methodological logic for the thesis, and the application of grounded theory in particular. The choices for methods are provided and how they are employed in order to address the research questions, and the epistemological assumptions are also justified in this chapter. The methods described include semi-structured interviews, and the accompanying or 'shadowing' of battery installers on the island, which a relatively uncommon method but has proven in this thesis to be an insightful one.

The specific methods of data collection included pre- and post-installation participant transcripts, accessed as part of the social science team. These interviews and transcripts provided participant responses to the technology in their home and an understanding of the interactions with installers, and their perceptions of value, agency, trust and the level of complexity of their systems. For the method of shadowing the installers was employed to understand the challenges that the installers faced in implementing the systems and to gain the other perspective in terms of the installer-householder interaction. The interviews with policy experts, which were separate from the social science team, were conducted to gain a holistic system understanding of socio-technical transitions, and for specific understanding on economic, social and equity challenges of transition. Data was accessed from a Bruny Island Participant's online forum to gain insight to troubleshooting interactions with participants and the pilot team (mainly a network utility engineer and a software engineer). This was helpful to see the themes in the question types and the types of challenges they faced in understanding how their systems worked, or how they wished it to work (related to desired agency). Interviews were also conducted with pilot partners (TasNetworks and Reposit Power) to gain an understanding of the technical challenges of the systems and how people interacted with new and changing knowledge. Interviews were conducted with the pilot researchers (from ANU and USyd) to discuss the cost, benefits and values of the systems; and the pilot lead to discuss the effect of leadership style and strategic niche management processes that may have occurred during the pilot.

Quantitative and qualitative methods were employed for a cost-benefit analysis as outlined in detail in Chapter Seven to interrogate theoretically the types of values; particularly economic, and decision-making as it relates to potential prosumers. In practice, one participant was analysed as an example in depth to gain empirical evidence that related more widely to the challenges of upscaling where the consumer decision-making is considered central to a transitioning system.

Chapter Four — Strategic niche management and governance: An exploration of the CONSORT pilot

The CONSORT pilot itself was analysed as the pilot unfolded from a social science standpoint. The chapter outlines the genesis of the pilot and the cross-disciplinary interactions that brought it about. Research leads were interviewed for this chapter to add to an 'insider's view' or partly ethnographic approach of the pilot and to demonstrate elements of SNM theory in practice. SNM is central to this chapter, with a focus on SNM-like practices within CONSORT and learnings in terms of policy implementation, network governance, and problem-solving that help accelerate the pilot's success in terms of the diffusion of knowledge and enhancing interdisciplinary learning.

Chapter Five — The pre-conditions of acceptance for a prosumer-led transition to a future smart grid

The focus in this chapter is the concept of consumers transitioning to prosumers and this transition being of core influence on the energy system. From a network perspective this presents a significant challenge in terms of understanding how to engage with consumers to trade their distributed storage behind the meter. This chapter focuses on a possible process that might support consumers to transition into prosumers so that the energy system may transition in a somewhat orderly manner to increased levels of distributed storage. This focus significantly relates to a socio-technical system transition and is also recognised by Australia's peak government energy agency (ARENA) where ARENA's current CEO describes distributed storage as a household energy 'revolution' while also recognising the threat of leaving distributed storage to track towards an unmanaged, ad-hoc transition. This thesis fundamentally argues a position of *management*; whereby significant innovative technologies, (where smart batteries are an example) should be managed, coordinated and visible to the network, *'If not, the uptake of distributed energy could be rapid and disruptive, making the electricity system less secure and reliable and more expensive to run'* (ARENA, 2019a).

This chapter investigates the underlying conditions be to enable the transition from a larger-scale, network perspective. Where the scale of analysis of the previous chapter was at a householder-installer implementation level, this chapter looks at both the network perspective, but through the lens of personal (i.e. 'consumer') perceptions and responses that relate to technology acceptance. This thesis claims that the network perspective on transition combined with the small-scale personal pre-cursors of technology acceptance (e.g. agency and trust) offers a novel angle with an empirical case.

This chapter, as a paper, proposes a theoretical sequence or a heuristic for new technology acceptance in energy consumers for an electricity transition — based on engagement; agency and choice; and trust. This relates to this overall thesis, specifically in regard to challenges within a transition where consumers (as energy citizens) are centrally placed within the energy system of increasing complexity. This approach is at the network-level and the new theory is supported both through previously existing scholarship as well as the empirical research on the CONSORT pilot.

Chapter Six — The evolving role of battery system installers within a transitioning electricity sector

This chapter is concerned with the battery installers because it was found through the CONSORT case that they had greater, more pivotal influence on the success, or not, of implementation than appreciated at the start of the CONSORT pilot. The installers, conceptually, could be envisaged as both STS innovation intermediaries (with unstable, radically innovative features within their roles); and as street-level bureaucrats (stable, incrementally innovative features within their roles) from a policy implementation perspective. This bringing together of both streams of scholarship was a novel contribution to the thesis.

The smart-battery installers interact with the householders at an intimate level (face-to-face, in their homes, providing advice). They are the interface between the pilot objectives and the householder expectations. The conceptual work of this paper drew on the role of intermediaries which catalyse innovation and transition; it then drew on SLBs from the policy implementation scholarship. This enabled possible a future (SLB) vision for intermediary functions within a post-disruption, stable policy and regulatory environment.

Chapter Seven — A sociological perspective of cost-benefit analyses for residential storage systems

This paper links to the previous paper from the point of view of the householders being centrally placed as agents within a transitioning energy system. The focus is on a micro level and importantly, from the householder's perspective, rather than from the network perspective which was considered for the previous paper. In this paper, the focus relates to householder decision-making and specifically how it relates to the cost of smart-battery systems. This question of cost-effectiveness is perceived by industry and governments as a key barrier and enabler for uptake or upscaling of battery systems. This concept of cost effectiveness was of interest for the CONSORT pilot overall; however, this paper provides a sociological critique and argues that determinants of price and cost are only a partial answer in terms of consumers transitioning to prosumers whilst simultaneously a transition of the energy system towards greater distributed storage. This chapter applies the CBA methodology because it is a ubiquitous method for decision-making in governments relevant here because it is already used as a way of advertising by battery manufacturers. This is important to appreciate because reducing electricity bills; and the capital costs of battery systems appear to be accepted as the two most important decision-making factor for consumers in Australia (Godfrey et al., 2017, p.75, figure 19).

Overall, the CBA is explained as being one methodology within a vast range of decision-making typologies. The assumptions and limitations of CBA are listed, and the methodology is analysed in the context of CONSORT participant household (BT112). In summary, this chapter provides a micro-perspective of transition, using a well-known decision-making tool (CBA), yet applies a sociological lens on drivers of transition.

Chapter Eight — Discussion and Conclusions

The final chapter of the thesis answers the overall research question. The highlights of the key findings of the chapter-by-chapter findings are presented as they relate to the theoretical framework of the thesis. A synthesis is provided and overall conclusions, including an explanation of the original scholarly contributions.

In summary, this thesis represents a fast-growing body of research which is investigating ways that a sustainable transition within the energy system may be accelerated, and how it may be navigated. It asks, what is possible from a governance, policy and management point of view? The case study of a smart grid as an innovative technology and how this might successfully upscale in an orderly manner is a key aim. Now that the thesis outline has been detailed in this introductory chapter, Chapter Two next discusses the areas of scholarship in depth and forms the theoretical basis for this doctoral study.

Chapter Two

The conceptual framework for the research on the CONSORT smart grid pilot

2.1 Background and Introduction

This chapter discusses scholarship that engages closely with the PhD research, and builds a conceptual framework for the thesis which is reasoned and justified. The PhD case study is described because it forms the basis of this field of enquiry and it provides a rationale for the choice of literature in this chapter. The case study is a smart grid pilot on Bruny Island, Tasmania, comprising 34 households with solar PV (i.e. small-scale renewable energy), and internet-enabled or 'smart' batteries that trade with the electricity network in a manner that economically optimises for the household via software; hence, the pilot is referred to as a 'smart grid.' The CONSORT pilot was an unfolding process of a socio-technical rollout and of policy implementation — through policy defined by a government agency, ARENA, and the pilot partners within the trial.

The key question posed in the thesis, within the context of a *deliberate acceleration of transition* (Roberts & Geels, 2019) and which is examined by this review is: **During a time of systemic disruption within the electricity sector in Australia, how might a transition to smart grids be encouraged to be accelerated and governed in an orderly manner?** Correspondingly, literature was reviewed that examines innovation, with regard to both policy and technology. The CONSORT pilot (the case study) is an innovative experiment: it is a blueprint for part of a possible future electricity system. The case study is an experiment within the wider 'large technical system' (LTS) of the electricity sector. As a large technical system that sits within, and serves society (Hughes, 1983, 1987), the electricity system is therefore referred to as a *socio-technical system* (STS) (Geels, 2005; Markard, Raven, & Truffer, 2012, p.956).

The case study is therefore theoretically sited as a socio-technical experiment or 'innovation niche' within a socio-technical system. Further, it is an experiment in deploying or implementing a new socio-technical system component, and so academic scholarship on policy implementation is highly relevant and is reviewed here alongside the socio-technical systems literature. Thus, there are two main lines of enquiry in terms of existing scholarship: socio-technical systems theory, and governance (policy implementation in particular). Socio-technical systems theory provides a contextual framework for the case study; while policy implementation scholarship provides insights into innovation dynamics and possible ways of responding to the challenges of governing of technological change. These two high-level lines of enquiry — of the theoretical positioning of the CONSORT pilot, and how it could be managed through greater policy understanding — are considered with a fundamental overarching question in mind: **'What are the pre-conditions for innovation to breakthrough to the mainstream?'**

Now that some justification of the argument and the supporting literature has been outlined, an overview of the two innovation literatures is presented below, namely socio-technical systems theory, and governance (including policy implementation).

2.2 Socio-technical Systems (STS)

Socio-technical systems (STS) theory emerged from earlier understandings of Large Technical Systems (LTS) (Bolton & Foxon, 2015, p.539; A. Smith, Stirling, & Berkhout, 2005, p.1507), where large-scale shifts in societal-based technical systems — such as the development of western centralised electrical systems — were recognised to have powerful non-technical influences that shaped the direction and nature of innovation. As Hughes describes in relation to energy utilities, 'non-technological factors of cultural context… [are highly influential, and the] evolution and style of regional utilities cannot be explained without reference to politics (i.e. issues of governance), especially legislation' (Hughes, 1983, p.405-6).

Much of the discussion on STS literature in this chapter concentrates on what is referred to as 'innovation niches' or niche-scale experiments. A niche comprises a small part of a socio-technical system, but is not yet widely deployed (Geels, 2002). A niche experiment or 'experimental pilot project' is at a scale which is smaller than the niche-scale, and within the innovation niche (Raven, Van den Bosch, & Weterings, 2010, p.466 Figure 1) and this is because an innovation niche may comprise a number of niche experiments. Here, in this review the 'niche experiment' concept is applied as representative of the case study (the CONSORT pilot) because it is at a sub-niche-scale within an innovation niche of 27 Australian projects variously related to the development of battery storage technologies (ARENA, 2019b). CONSORT, when pitching to ARENA for funding in 2015, was defined as sitting at an early stage of technology readiness. On a scale of 1) research and development, to 2) demonstration and 3) deployment, CONSORT was at the research and development stage and not yet at the pilot stage. Given that the research that CONSORT proposed was a single pilot, CONSORT is argued to sit at the niche-scale within the MLP parlance. See figures 2.1 and 2.2 for further description of the MLP and where the CONSORT project sits within this theoretical context. The term niche experiment is also suited where an experiment or pilot sits within the *individual* development and *prototyping* phase of the early stages of an innovative socio-technical system and does not yet have currency as part of a socio-technical system.

2.2.1 A 'systems-thinking' approach to transformation

Thomas Hughes' 1983 book *Networks of Power: Electrification in Western society, 1880-1930*, traces the trajectory of western energy systems development. Hughes focused on this early period because he recognized that: the main *evolution* of centralised electricity systems was complete by 1930 with expansion occurring afterwards; and, exploring the structural transformation of the system, rather than *expansion* per se was important. As discussed in Chapter One, centralised electricity systems are currently under pressure to rapidly transition, to make deep structural changes, so this focus on innovation and evolution of system change, rather than expansion of a set system is highly relevant to this thesis.

Hughes understood energy system transitions to be significantly influenced by non-technical aspects of the electricity system, including issues of governance, economics, cultural values and consumer acceptance, and he employed the example of the so-called 'battle of the currents' to demonstrate this influence. The battle of the currents arose with disagreement about whether electricity should be generated and transmitted using Alternating (AC) or Direct (DC) Currents. Components and standards, indeed entire electricity systems, Hughes argues, were established, not due to technical superiority and scientific knowledge, but, in the 'battle of the currents' example, due to the struggle and negotiation with manufacturers that chose one or the other current types. Hughes cites numerous examples where aspects of governance, economics and other non-technical reasons shaped the *uneven* nature of electricity system development throughout the US, Germany, and the UK (Hughes, 1983, pp.127-128).

Hughes' explanation for the structural influence and the early market domination that Edison and company had on society-wide large technical system (LTS) LTS change is based on an approach to change. The concept of LTS is very similar to socio-technical system (STS) change, without directly naming up the societal, and non-technical elements that involve large-scale transition. According to Hughes, the LTS framing provided a 'systems-thinking' approach, which included being cognisant not only of technical integration, but of wider social, governance and economic factors. The systems-thinking approach is strategic with its insight into the importance of internal consistency, compliance and integration (Hughes, 1983, pp.21-22). In this regard, and for this thesis the application of a systems thinking to a LTS transition is equally applicable to STS transition.

Nevertheless, a changing system of this scale is intractably complex. According to Hughes, the basis for centralised electricity was driven by a 'radical change in needs and attitudes' (1983, p.324), which shaped the future system in unforeseen ways. An example of this was the legal boundaries of municipalities in London in 1926, where the progress and expansion of electricity utilities was stymied geographically. By comparison, the 1920s saw Sydney and Tasmania as more advanced for the electrical age, despite Australia's small stature in the world, something that Hughes attributed to a lack of governmental hindrance that allowed advanced, centralised electricity systems to develop (Hughes, 1983, p.351-352).

There are many competing objectives in a large and changing socio-technical system, and a high-level, systems-thinking approach holds logical appeal in terms of understanding the elements that thwart system transition, or enable it. After Hughes, other scholars investigated the degree of agency in LTS transformation, specifically, the ability to steer and influence system-wide innovation. For instance, Shove and Walker (2007) refer to the 'firmly rooted' tradition of systems thinking as applied to socio-technical transition theory, which was also central to the work of Geels (2002, 2004 and 2005). These authors suggest a 'need for fresh approaches and forms of governance capable of engaging with complex challenges' (2007, p.763). Shove and Walker acknowledge that the transition management literature refers to 'processes of governance' (2007, p.764); but despite this, the authors are cautious and pessimistic, and essentially argue that sociotechnical systems are unsteerable due to the complexities of inequality, conflict or issues related to governance (2007, p.768).

Other scholars argue that agency does exist, and that influence is possible within STS evolution. For example, Lopolito, Morone, and Taylor (2013) link increased agency within niche experiments to an increased spread of information, and to provision of government subsidies for R&D experiments. These influences arguably increase actor's or agent's positive expectations towards the deployment of new technologies (Wolfram, 2018) — suggesting that increased, grassroots agency for sustainable niche development in cities can be driven by 'embedded holistic innovation' and 'novel community-oriented governance modes' (Wolfram, 2018, p. 11)

The important concepts of engagement and management, as well as agency and trust, as influencing overall acceptance are examined closely in Chapter Five, and the concept of consumer acceptance as a crucial barrier or enabler of socio-technical transition is revisited later in this chapter in the section on social embeddedness using the Davis Technology Acceptance Model (TAM).

2.2.2 Socio-technical system change – a combined systems and management approach

One aspect of the now large body of scholarship on socio-technical systems, with high significance for this study, is that on sustainability transitions. Markard et al. (2012) conducted a substantial survey of sustainability transitions literature, thematically analysing 540 papers to create a basic conceptual framework. They found the literature reviewed was cross-disciplinary, including 'management studies, sociology…[and] policy studies' (Markard et al., 2012, p.955).

Markard et al ask '[if] incremental change will not suffice…[then] how to…govern a transition[?]' (2012, p.955). From the 540 papers reviewed, four frameworks were identified, and these are: transition management; strategic niche management; the multilevel perspective on socio-technical transitions; and technological innovation systems. Though not identified by Markard et al. (2012), it does appear that these frameworks identified fall into two groups – broadly the frameworks are either *management approaches* (transition management, strategic niche management); *or systems approaches* (the multiple level perspective on socio-technical transitions, and technological innovation systems).

Arriving at this conclusion by another path — a path that combines agency, management, and policy within STS, this literature review isolates, then integrates, either side of the frameworks that Markard et al. (2012) propose. What follows explores socio-technical systems and governance. Specifically, and firstly, downstream of STS is the multiple level perspective, and within this sits strategic niche management, which is a focus of this review. Secondly, downstream of governance is network governance and, through this lens, policy implementation is reviewed as a second focus.

I firstly turn to a socio-technical systems framework — the multiple level perspective framework — as conceptualised by social scientist and former engineer Frank Geels.

2.2.3 The multi-level perspective within socio-technical systems

Geels (2002, pp.1261-1263; 2005, p.449) conceptualises his multiple level perspective (MLP) as providing a conceptual framework to better understand innovative change within society that evolves from small-scale to large-scale over time. Geels describes the different scales or 'levels' as niche, regime and landscape. Socio-technical experimentation, Geels argues, occurs at a niche level, and for a technological innovation to gain traction it needs to breakthrough to the regime level (i.e. be more widely deployed).

Geels shows that there is inherent stability in current socio-technical regimes – due to 'legally binding contracts, cognitive routines, core capabilities…favourable institutional arrangements and regulations' (Geels, 2005, p.450); and that innovation occurs in these regimes in an *incremental* manner. By sharp contrast, small-scale niches can enable new (*non-incremental*) technology development in 'relative isolation' (2005, p.450). 'Niches are important, because they provide space for learning processes on several dimensions, e.g. technology, user preferences, regulations, infrastructure and symbolic meaning' (Geels, 2005, p.451). Examples are provided by Geels of niche, non-incremental development, including the evolution and 'mainstreaming' of the internal combustion engine and petrol-based automobile, and telephone communications. For example, the landscape level change of the telephone to the internet was not a given path, and was influenced by many actors, interactions and 'power struggles' — and yet it occurred despite it being 'difficult for established firms to switch to competency-destroying breakthroughs' (Geels, 2005, p.447).

The classic Geels MLP schematic, which forms part of the theoretical basis of this thesis, is presented in Figure 2.1 below.

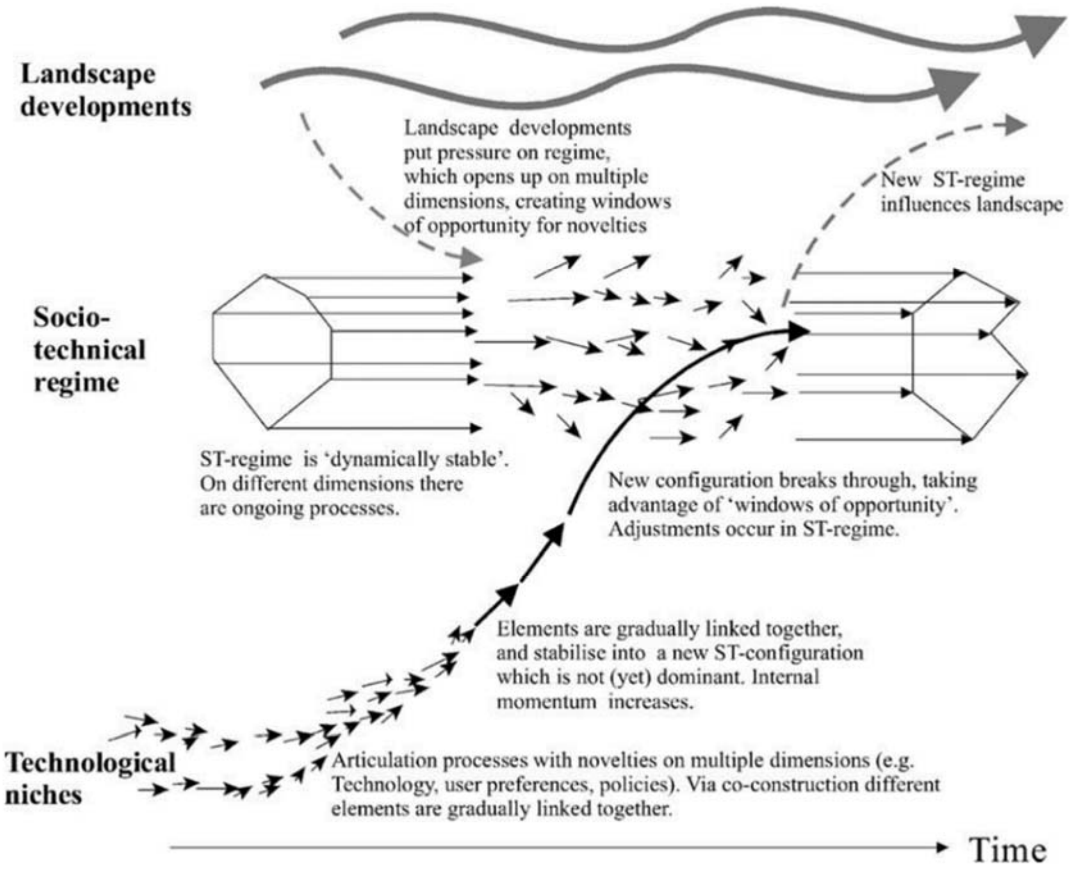


Figure 2.1. A dynamic multi-level perspective on system innovations, Geels (2002, 2004)

Below is a slightly nuanced description of the CONSORT pilot in included, placing the pilot as a niche experiment, and within the regime, because it is supported by the incumbent utility.

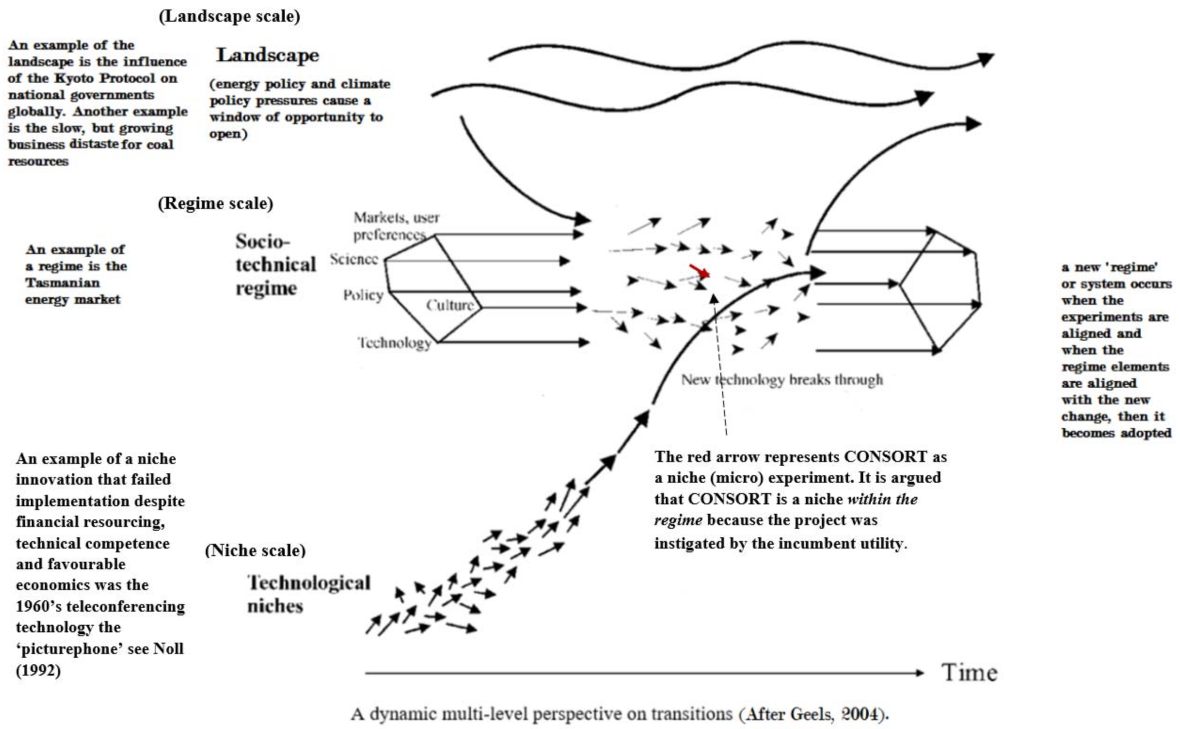


Figure 2.2 The multiple-level perspective of socio-technical system change applied to Bruny Island

Overall, the MLP framework proposes small, peripherally nucleating, radical changes by new entrants as opposed to incremental change, and/or centrally nucleating change by incumbents. On this point, Hörisch (2015) synthesises the MLP literature with sustainable entrepreneurship literature. Horisch's main criticism of MLP is the framing of the incumbents versus entrants, as MLP is primarily interested in niche innovations from new entrants and not from established firms. Horisch, on the one hand, agrees that large established firms are unlikely to pursue radical innovation because it causes instability to the regime, which supports the MLP theory. On the other hand, Horisch argues that the incumbents strength is 'their ability to pursue process innovations...in an economically efficient manner' (Hörisch, 2015, p.288). Horisch adds to MLP theory by conceptually situating R&D within government departments and firms in the niche innovation space.

Additionally, Horisch (2015) along with Seibert, Silver, and Randolph (2004), Smith, Stirling, and Berkhout (2005) and others criticise MLP for a '*lack of agency*,' including a lack of regard to the role of governmentality and politics in influencing change. Other recent scholars of STS theory, Taylor, Bolton, Stone, and Upham (2013) also interrogate ideas of actors and agency within the STS system, but add to this a critique of the way scale and system evolution is approached. Taylor et al. (2013) use the STS literature to 'identify some of the most important contextual factors which are likely to influence storage deployment' (2013, p.231) in the UK. The authors create frameworks for three future energy pathways: user-led, decentralised, and centralised, and these scenarios relate to scale; they term these micro-, meso- and macro- (consecutively). Each of these scale-dependent pathways has challenges relating to business strategies, different roles of users and institutional changes required to facilitate the change (2013, p.241):

> 'While macro-scale storage is likely to be viewed in a similar way to other industrial installations, micro-storage will probably need to satisfy many of the criteria that are normally associated with consumer devices. Affordability, controllability, performance, aesthetics and fit with the domestic or work habits will therefore all be important.'
>
> (Taylor et al., 2013, p.242)

Consumer-driven transition to renewables was faster than for large-scale renewables because the barriers for smaller-scale systems compared with the (larger) centralised incumbent regime are lower: '*distributed* electricity storage currently faces a number of challenges…resulting from poor alignment of the current regulatory regimes' (Taylor et al., p.231). Further, the authors argue that the large scale contrasted with the small scale has 'innovative processes…[of]…a different character' (Taylor et al., 2013, p.231) and that there are issues of mismatched scale.

Though not directly expressed by the authors, by slight extension, a centralised electricity system that attempts to retrofit small-scale solutions (such as solar PV and batteries) could be expected to strike all the problems the authors outline, from institutional, business and social barriers, due to this mismatch in scale between the old and the emerging systems. Conversely, when the scale of existing infrastructure and emerging technologically innovative solutions are at the same spatial scale, deployment might be expected to occur more easily. Although centralised energy systems are complex and large, it is argued that it is the responses at the smaller scale that create significant technical and regulatory challenges.

For A. Smith et al. (2005), the concept of coordination within the regime is a key theme as a policy constraint or enabler between actors, agencies, resources, capabilities and expectations and policy objectives. These researchers link governance and STS theory where they define a 'quasi-evolutionary model' of transition theory. Again, as other scholars have noted, MLP appears to lack a component that is able to incorporate agency. Bolton and Foxon (2015) also analyse the challenge at the intersection of governance (of the energy system) with socio-technical systems theory. They propose that the predominantly short-term focus, as measured by the length of an electoral cycle, is unsuitable for long term infrastructure governance; and that this explains why there is 'relatively little understanding of the social and institutional dimension of these systems and appropriate governance strategies' (Bolton & Foxon, 2015, p.538). Bolton & Foxon conclude that a 'more "innovation friendly" governance model' (2015, p.539) is required to face energy system challenges. However, they do not outline in any detail what this innovation friendly governance model might look like.

Consumer-driven change based on affordability, controllability, performance as expressed by Taylor et al., (2013, p.242) among other factors, affect consumer decision-making. Consumer decision-making typologies, and the financial and non-financial reasons for decision-making in relation to smart-batteries are investigated in much greater detail in the paper that forms Chapter Seven of this thesis.

2.2.4. Strategic niche management (SNM)

In addressing governance and agency aspects to socio-technical systems theory, the concept of strategic niche management becomes evident, because it takes as a starting point that it is possible for governments and other types of organisations to influence change; and that agency is of significance in relation to the concept of managing a transition. Thus, analysis now turns to strategic niche management (SNM).

Kemp, Schot, and Hoogma (1998) describe SNM as a methodology that provides 'a way to manage the transition' in a deliberate, targeted way that can accelerate a promising technology from obscurity and experiment to 'a new regime' (1998, p. 175). The concept of SNM is unusual as it presents both a policy theory as well as a methodology for managing innovation. SNM-learning and innovation through transition experiments offer a potential policy toolkit for adaption to structural problems in modern society (Raven et al., 2010).

SNM emerged in the Netherlands in the 1990s and was developed by researchers in close collaboration with government. The European Union sponsored SNM as a research project with the ambition of using it as a policy tool for transition, technological innovation and social learning (Loorbach & van Raak, 2006, pp.3, 6). Originally, the intention of SNM had been for use in governments in setting the framework for the early stages of niches. This is what distinguishes SNM from other STS theories — the central role of government, and governance — hence it is used here to inform the PhD theoretical framework, alongside policy implementation theory.

According to SNM scholars, a socio-technical transition may be facilitated through strategic management practices of promising technologies at a small experimental scale. For Kemp et al. (1998, p.192), SNM lies on the 'spectrum of policy instruments…[where SNM]…may act as a stepping stone' toward a sustainable future. Mourik and Raven (2006) reiterate the prevailing viewpoint about SNM, which is that scaling up is the translation from 'radical sustainable innovations' to 'successful implementation.' Markides (1997) echoes this thinking; describing niches as strategic innovation for system-wide changes, and that this is the central concept for strategic niche management.

SNM, firstly, offers a management approach that supports small-scale (niche) innovation, where the 'level of analysis…is often (a series of) experimental projects such as piolt[s]' (Raven et al., 2010, p. 64): and secondly, agency is intrinsic to SNM. SNM is a concept that measures participation, even if this is measured by proxy. Regarding the meaning of 'proxy,' consider the following — agency is commonly related to governmental or political influence (Dixit, Grossman, & Helpman, 1997, p.752-753), and resource and finance (Jensen & Meckling, 1976, p.305). However, also consider that if participation and engagement are increased, they thereby increase influence and power because a high level of agency implies a high level of participation. Thus, agency is related to influence, and participation increases this (Chess & Purcell, 1999, p.2685). The outcome argued by this premise is that agency is linked to participation, which, similarly to advocacy rights, is held as a democratic principle (Rose-Ackerman, 2007, p.31). These linkages are important to clarify because they support the theoretical basis of the PhD case study, which is about the governance of distributed control by consumers and the future influence of citizens driving change.

The founder of the MLP, Geels, addresses his critics on the subject of agency (Geels, 2011), and also investigates SNM in relation to MLP. Schot and Geels (2008) undertook a survey of 10 years of SNM literature to 2008, and they found that the literature reveals successful SNM results due to the management of three key elements, 1) expectations, 2) networks and 3) learning processes. These key elements have also been reinforced since their review by other theorists such as Hermans, van Apeldoorn, Stuiver, and Kok (2013) and Lopolito et al. (2013).

However, despite the great promise that SNM may hold, it has to date mostly been applied to historical case analyses (Raven et al., 2010, p. 66), and has not yet been successfully demonstrated for application as *future* scenarios or strategies (Adamides & Mouzakitis, 2009). This is also represents an important scholarship gap as well as a practical and policy gap — 'The fact that SNM is not yet formulated as a practical policy tool is complicated by the lack of empirical testing of SNM...SNM thus faces an operational gap' (Loorbach & van Raak, 2006, p.13).

A key government-funded report on SNM states that what 'is still lacking are detailed and practical *guidelines* for practicing project- and niche-builders' (Mourik & Raven, 2006, p.4, original italics). There is a gap in the scholarship here, and hence the focus of this PhD in investigating the application of SNM in relation to policy implementation and the implementation of the pilot itself.

Key elements of strategic niche management scholarship are explored below in further detail, because of its strong relevance to the CONSORT pilot namely: A protected niche; Upscaling; Networks and alignment of stakeholder visions; and Learning.

2.2.4.1. A protected niche

All SNM scholarship is based on the concept of a 'protected space' for innovation to develop as a critical pre-condition for transition to occur. A protected space in this context can mean policy support, grants, seed funding, government-funded R&D pilots, subsidies or other measures that encourage behaviour change in the market. A protected space can also refer to industry R&D hubs that tolerate early prototype inefficiencies while the niche technology is buffered from full market forces (Hughes, 1983; Witkamp, Raven, & Royakkers, 2011). Providing grants (such as ARENA does in the case of CONSORT) is a deliberate intervention from market forces that are 'temporarily protecting the innovation' (Raven et al., 2010, p. 63), these experiments (such as the CONSORT pilot, might be considered as an 'artificial nice' (ibid, p.63). A protected space includes non-financial (regulatory) protection, such as a 'legislative space' to experiment (Hermans, van Apeldoorn, Stiver and Kok., 2013, p.613) insomuch that it can allow testing of a technology to occur, without facing regulatory barriers.

One of the central reasons for a protected space is that it can create market fairness for new entrants. Kern and Smith (2008, p.4094) observed this in practice. They conducted 27 interviews in the Netherlands with policy and decision-makers, businesses, researchers and NGOs and found that implementation of protective SNM processes 'creates a more level playing field' for high-risk, high-potential experiments.

Overall, the goals of SNM are to articulate changes required for niche success; to increase learning (technical and social); to help trigger the leap from pilot to mainstream; and to support the coordination of actors linked to the niche (Kemp et al., 1998, p.187).

2.2.4.2. Upscaling is the intent of SNM

Upscaling of a technology or system, or the diffusion of innovation, is the intended outcome of SNM, yet there are a number of barriers to upscaling. These include barriers of policy and regulation, production and infrastructure, undesirable environmental effects, psychological barriers, and low citizen demand (Hoogma, Kemp, Schot, & Truffer, 2002; Kemp et al., 1998). Strategic niche management is an approach that aims to reduce these barriers, through experimentation, learning and management within a protected space (as discussed above). Mourik and Raven (2006), Schot, Hoogma, and Elzen (1994), Xue, You, Liang, and Liu (2016), and others, have analysed several electric vehicle (EV) case studies through the lens of analysis of SNM, and this analysis confirms that upscaling is the key objective or outcome of SNM. The investigation by Xue et al. (2016) highlights the effect of SNM leading to a large-scale rollout of EVs in three Chinese provinces, and these authors, as others, determine that success occurs due to supportive policy networks, aligned stakeholder visions and learning, the effects of which are elaborated below.

2.2.4.3. Networks; alignment of objectives; and learning

Hermans et al. (2013) state that the influence of a network, or a 'collaborative innovation network', is one of the strategic niche management conditions that enable a type of socio-technical evolution to occur. Their case study comprised twenty-one (farm-scale and regional-scale) projects within an agricultural-cooperative niche from the Netherlands. These cases had a 'legislative space to grow' which aided their development from niche to mainstream (Hermans et al., 2013, p.613). Importantly, it was recognised that an initial outcome of lower technical performance was accepted as part of the experimental process, and that there was a close focus on 'social learning and knowledge co-creation' (Hermans et al., 2013, p. 614). According to Schot and Geels (2008), Kemp et al. (1998), Hermans et al. (2013), Lopolito et al. (2013), Xue et al. (2016) and others, in order to be successful in upscaling an innovation niche, the following is required: stakeholders' expectations need to be robust and clearly defined; networks need to be broad, deep and organisationally linked; and learning should be deeper than just data gathering. This range and depth of qualities allows a questioning of assumptions that enable the consideration of radical innovations. Learning takes a number of forms including learning by diffusion 'technology diffusion', and through 'problem solving networks' (Adamides & Mouzakitis, 2009, pp.176-178). These authors analyse three case studies of industrial ecosystems, and they found that wide acceptance springs from '[t]he installation of knowledge diffusion mechanisms and the implementation of policies for the gradual withdrawal of protection' (Adamides & Mouzakitis, 2009, p. 176).

In summary, strategic niche management is a policy measure whereby R&D can be demonstrated for suitability for upscaling in the real world, helping to correct market failures through assisting in implementing sustainability transitions (Schot & Geels, 2008, p.547). Strategic niche management scholars recognise the key ingredients for SNM success include a protected space; aligned objectives; learning; and networking and support of innovation (Hermans et al., 2013; Lopolito et al., 2013; H Lovell, 2007; Schot & Geels, 2008; Xue et al., 2016). SNM is recognised widely as a potential method to upscale within the niche, to the point of deployment, within a larger system – and this is a description of implementation *en masse*.

Although SNM is framed as a policy measure by Schot and Geels (2008) and others, SNM scholars have not tended to link across to theories of policy implementation. Correcting this oversight is one of the conceptual objectives of this thesis. Much is offered by SNM scholars about what SNM is and its attributes, but scarce guidance is provided to link across to policy implementation, which leads me to consider the policy implementation literature below.

2.3. Network governance and policy implementation

Governance is about social coordination in the forms of administration, politics, and *public policy* (Bevir, 2009, p.vii-viii) — however — it is policy, and in particular, *policy implementation,* which forms the second major theoretical undercurrent of the thesis and hence of this literature review. It is noted at the outset that this literature review leans towards the theories of non-regulatory governance measures (Althaus, Bridgman, & Davis, 2013, pp.93-95). Regulatory measures within governance (Levi-Faur, 2011, p.4), commonly referred to as command-and-control or top-down policy approaches, are important and effectual for many areas of policy (Althaus et al., 2013, pp.96-97; Sabatier, 1986, p. 36), including the military, emergency services, national security and enforcement of national and international standards.

However, the CONSORT pilot — the case study of this PhD — is an experiment involving a new technology within a community, and thus is a form of implementation that engages with individual values, is specific and localised, and considers values of trust and consumer engagement agency. These case study characteristics align strongly with policy implementation scholarship that incorporates feed-back and learning from the bottom-up, which includes stakeholder management and knowledge sharing (Althaus et al., 2013, p.176, sidebar ; Elmore, 1979; Khan, 2016, p.10; J. P. Lester, Bowman, Goggin, & O'Toole, 1987, pp.207, 209; Matland, 1995; Sabatier, 1986). Here it is suggested that the concept of *policy development* is situated within the field of governance concepts, and that an understanding of the utility and the merits of *policy implementation* within a wider framework of network governance is deserving of focus. More specifically, it is proposed that bottom-up policy implementation theory resonates with network governance strategies and might provide pathways for successful policy implementation within socio-technical systems, such as for a successful deployment of smart grids. Further synergies and overlaps between scholarship on SNM and policy implementation are also identified and explored here.

Network governance, or collaborative governance, is defined by Ansell and Gash (2008, p.544) as 'A governing arrangement where one or more public agencies directly engage non-state stakeholders in a collective decision-making process that is formal, consensus-oriented, and deliberative and that aims to make or implement public policy or manage public programs or assets.'

Others extend this view, 'Governance is about managing networks' (Rhodes, 1996, p.658), and essentially is the interaction of 'coordinated actors' (Bevir, 2009, p.7). The great potential of network governance is in the 'general virtues of speed, flexibility, inclusiveness, ability to cut across different jurisdictions, and sustained focus on a specific set of problems' (Slaughter, 2004 in Kahler, , p.28, undated), and it is a type of 'management with stakeholder engagement [that] is increasingly employed around the world' (Koontz & Newig, 2014, p.435). Network governance enhances the ability of the state to effectively govern due to a combination of top-down measures and forming partnerships or linkages with NGOs (Bell & Hindmoor, 2009, pp.1-2). Thus, due to its rich, collaborative stakeholder interactions, network governance is part of a body of scholarship that includes bottom-up policy implementation, described further below.

2.3.1. Policy implementation, backward mapping and distributed agency

Overall, network governance supports policy implementation theory, including ideas of innovative collaboration (Sørensen & Waldorff, 2014, p.2), and ideals of high civic advocacy or participation (Althaus et al., 2013, pp.93-94). Participation is intrinsically connected with agency; hence network governance is conceptually linked with high agency. Moreover, network governance is sought as a method for bridging the 'implementation gap' which is central to this thesis. The 'implementation gap' is the gap between implementation research and practice (Olswang & Prelock, 2015, p.1818). In other words, the reality of policy implementation often does not match the imagined ideals of a policy in theory.

Policy implementation is the end-point of policy design, and the study of implementation has been describes by Pressman and Wildavsky (1973, p.xv) as 'how ideas manifest themselves in a world of behaviour.' Historically, policy scholars first grappled with the theories of policy *development*, and then later with policy *implementation*, within the policy cycle (P. L. Hupe & Hill, 2016, pp.105-106, 114; J. P. Lester et al., 1987; Pressman & Wildavsky, 1973; Sabatier, 1980, p.538). Policy implementation has been relatively neglected:

'For all the attention to administration over the years, the nitty-gritty of implementation had been largely a background issue' (O'Toole Jr, 2000, p.264).

Various scholars have compared and contrasted the approaches of the two main categories of policy implementation, namely, 'top-down' (forward mapping), regulatory, command-and-control policies; against the 'bottom-up' (backward mapping), voluntary and grass-roots policy measures, as well as attempting to synthesise these approaches (Barrett, 2004; Elmore, 1979; Fiorino, 1997; Hjern & Porter, 1981; Koontz & Newig, 2014; Sabatier, 1980). What resulted from this dialogue was 'the synthesisers' — a new generation of policy implementation scholars, with an integrated approach (Paudel, 2009, p.43). The synthesisers argue that bottom-up and top-down policy implementation approaches lie on a continuum, that implementation is complex, has contingencies, and is not a 'binary' choice (Voss, Smith et al. 2009, p.279). Sabatier (1986) undertook a review of fifteen years of implementation literature and found that the type of approach best suited (top-down, or bottom-up) often depended on how many agencies were required to address the issue. For example, a one-agency solution finds that a top-down approach generally works best to achieve policy objectives.

It is noted here that the scholarship on implementation is wide and thus is abundant, for example, Hill (2005, Chapter 9, Implementation: an overview), and the important study of policy implementation failure at the large-scale (Pressman & Wildavsky, 1973). However, the concept of backward mapping is a narrower branch within implementation literature (Elmore, 1985; Fiorino, 1997). The term was first developed by Richard Elmore in his 1979 article 'Backward Mapping: Implementation Research and Policy Decisions'. There are several commonalities between bottom-up implementation and backward mapping approaches. Both policy areas are focused on implementation – the practical outcomes of policy. Also, both look to build consensus through stakeholders. The difference between bottom-up implementation and backward mapping is that there seems to be less emphasis on the hierarchical nature of policy in backward mapping, and that although backward mapping falls into the bottom-up category, it seems to be more precise with its focus on the *'local behaviour'* or expression of the policy and then working backwards to a policy decision.

Richard Elmore attributes the notion of backward mapping to a predecessor, Mark Moore (Elmore, 1979 p.602), but it is Elmore who develops the idea and brings it to wider attention. Elmore argues that an inescapable problem for the policy maker, in conventional, top-down policy making, (also referred to as forward mapping) 'is its implicit and unquestioned assumption that policymakers control the organizational, political, and technological processes that affect implementation' (Elmore, 1979 p.603). The rationale presented by Elmore is that backward mapping focuses on the '*specific behavior at the lowest level of the implementation process that generates the need for a policy'* (1979, p.604, emphasis added) and, once this is isolated or understood, then solutions for practical policies to affect change can be grasped. The central assumption is that *'the closer one is to* *the source of the problem, the greater is one's ability to influence it'* (Elmore, 1979 p.605, emphasis added). Both Elmore and a later theorist (Fiorino, 1997) suggest the advantage of backward mapping as a strategy is in producing a successful outcome where the top-down, forward mapping methods have failed, particularly in environments where administrative or governmental consensus is lacking, such as in the electricity sector in Australia currently. Backward mapping is designed to lead to incremental changes, 'ground level' flexibility and successful, predictable, policy outcomes. Fiorino (1997, p.260-261) uses the example of the US Environmental Protection Authority, whereby there was a lack of leadership agreement on 'desired levels and forms of regulation, policy fragmentation…[with issues of]…dispersed power, and technical complexity. For these reasons, an incremental, bottom-up approach, defined here as backward mapping, may be the only feasible regulatory reform strategy.' Further, Fiorino (1997, p.260-261) reports that 'the backward mapping process led to a list of 44 issues that stakeholders thought were important'. In other words, due to the complexity and lack of high-level consensus, the backward mapping process was found to be successful.

Backward mapping is also a term used within the socio-technical systems literature, for example by Voss, Smith, and Grin (2009) in their analysis of global energy systems transitions. Iterative forward and backward mapping helps avoid unintended consequences and increases 'understanding, participation and learning' and reflects the growing nature of 'distributed agency' (Voss et al., 2009, pp.279-281). The idea of distributed agency is related to behaviour change at the grassroots level; it indicates that behaviour from the bottom up is effectual, has consequences and can inform.

Backward mapping is acknowledged to have disadvantages, however: 'it is a slow and potentially costly way to accomplish change…[e]xtensive amounts of time are required to form stakeholder groups…[and] pilot projects…[and to] transfer lessons to other settings and sectors' (Fiorino, 1997, p.262). A core learning implied here is the influence of collaboration and participation, which is elaborated upon below within the next section 'Social Embeddedness and Acceptance.'

Before the next section, an important link is drawn between backward mapping and the scholarship of 'Street-Level Bureaucrats' (SLBs); which is also which is examined and extended in Chapter Six of this thesis. Both concepts lie within the policy implementation literature, and critically, *relate to understanding the implementation gap at the small-scale — that is, at the point that implementation occurs*. The foundation provided here on backward mapping further legitimises the value of the SLB scholarship explored in more detail in Chapter Six.

In brief, the understanding implementation gap and SLBs was pioneered by Lipsky (Lipsky, 1969). SLBs are typically public servants (such as police and teachers), that implement policy based on their professional judgement, experience, within the pressures of time and resources (Lipsky, 2010), and importantly, their discretion also allows them the ability to divert from formal policy and their overarching governance structures; and this critical effect on implementation outcomes is discussed in Chapter Six. Chapter Six investigates the role of SLBs as policy implementers through the example of the battery system installers on Bruny Island as quasi-SLBs. This scholarship is linked with the STS through the concept of innovation intermediaries, and is investigated fully in Chapter Six.

2.3.2. Social-embeddedness and Acceptance

A number of implementation theorists, among them, Nooteboom and Marks (2010), Miller, O'Leary, Graffy, Stechel, and Dirks (2015), Chatfield and Reddick (2016), Uzzi (1996) and Gudowsky and Peissl (2016), hold that the conditions for successful innovative policy implementation are in social-embeddedness, public engagement and cross-sector collaboration. At a fundamental level, '[e]mbeddedness refers to the process by which social relations shape economic action' (Uzzi, 1996, p.674) and it has its basis in public participation and engagement (Miller et al., 2015). For example, according to Miller et al. (2015, p.66), the 'problem' with the International Energy Agency Roadmaps and various government strategies is they are 'devoid of people' which indicates a lack of public engagement and social embeddedness as a consideration in these future energy scenarios. By contrast, this chapter suggests that ideas that are socially-embedded are ideas and policies that are *accepted*. For socio-technical transitions, the goal is the *acceptance* of new, beneficial (sustainable, democratic) technologies: because this leads to implementation success. A case study with strong relevance to the PhD that demonstrates social embeddedness is the work of Chatfield and Reddick (2016) on four Japanese cities rolling out smart meters. After interviewing numerous actors between 2011-2012, they found four elements that are required for 'implementing smart cities'; these are: resources, leadership, 'social-embeddedness, and citizen-centric e-governance' (Chatfield & Reddick, 2016, p.757). In the cases they review, the 'leadership network members' are industry players and a municipal government though, notably, but without explanation, they lack leaders from government. The smart city project for Kitakyushu city has embedded active citizen engagement as part of the charter, which proved to be a successful strategy.

Evidence of the relationship and power of social acceptance with policy success is also revealed in a US case study of impressive technical success combined with unexpected implementation failure, due to a lack of acceptance of the new technology. A United States firm, AT&T, invested a large amount of capital into R&D of a new technology (half a billion US dollars in the 1970s); the firm had an impeccable track-record, yet the result was total implementation failure due to lack of consumer acceptance. The ‘picturephone system’ technology was a hands-free video-conferencing telephone system, similar to the modern ‘Skype’ communication technology, yet ‘consumers simply had little need for two-way, face-to-face telecommunication…[and the]…market failure had little to do with either technology or cost’ (Noll, 1992, p.307). The technology turned out to be ahead of its time by two decades, but the implementation failure was *not* due to a lack of a protected niche, high resources or structural acceptance by the incumbent regime. It was due to failure of lack of engagement and of a deeper lack of consumer *acceptance*.

Surveys at the time revealed this lack of acceptance towards the idea of this new technology with one respondent stating ‘”I like the phone as Alexander Graham Bell intended it: an instrument for speech only”’ (Noll, 1992, p.315). Fundamentally, the benefits for use in business, such as reduced travel by using conference calls, were, at the time, either not understood or accepted by the public.

2.3.3 Conclusions and theoretical investigation within the CONSORT pilot

The CONSORT pilot is a possible blueprint for part of a future energy system. The core questions posed in this literature review were ‘During a time of systemic disruption, in what way might policy support accelerated innovation as well as orderly governance? And, theoretically, ‘What are the pre-conditions for innovative breakthrough to upscaling?’

Analysis of the scholarship produced an argument that two bodies of innovation literature are necessary to develop a framework of conceptual analysis for the smart grid pilot, namely literature on socio-technical system transitions from sociology and innovation studies, and network governance and policy implementation from the tradition of public administration and public policy. Thus, core elements of the smart grid pilot, which is also a socio-technical experiment, are conceptually addressed from a systems point of view and a management point of view: using SNM and policy implementation, both which champion agency and focus on the bottom-up detail of innovation processes.

It is argued in this thesis that SNM, (from the STS scholarship), has the potential to enhance accelerated innovation; and that SLBs (from the policy implementation scholarship), also has the potential to support an accelerated innovative breakthrough. The niche-regime boundary from the STS scholarship is identified as the implementation gap from the policy implementation scholarship.

It is argued that the features of SNM and the impacts SLBs within the energy sector can contribute to an orderly approach to managing innovation in times of transition. These effects and impacts are investigated and evidenced throughout the empirical chapters of this thesis.

In summary, the first set of literature reviewed on socio-technical systems transitions theory focused on strategic niche management; and one of the applications here is where the Bruny Island pilot sits within MLP theory; that is, how the smart grid pilot, as an experiment, fits within existing STS theory. A secondary objective in the application of the theory is in defining the delineation of the incumbents versus new entrants for niche innovation which is proposed by MLP theory. The CONSORT pilot had both a utility incumbent (TasNetworks) as well as a new entrant (Reposit Power) as project partners. Overall, strategic niche management as applied to the pilot, speaks to methods that would increase knowledge sharing and deployment. From a SNM point of view, the smart grid pilot provides an empirical case of deployment that is contemporaneous (as opposed to historical) and a case that is novel (and not electric vehicles), which addresses a gap in the scholarship. Further, the strategic niche management literature establishes the importance of the concept of agency within socio-technical system development, and the idea that change can be somewhat influenced through governance.

SNM has not thus far been examined in conjunction with the policy implementation literature and so there is a scholarship gap here, which this thesis focuses on, given the synergies between SNM and backward mapping policy implementation theory. SNM is investigated in the case study chapter, Chapter Four.

The second set of literature reviewed was policy implementation and network governance, with a focus on backward mapping, which has potential to have social learnings that impact implementation such as trust and acceptance of the technologies. As the smart grid pilot is an experiment in implementation, the policy implementation literature engages with this on the community and individual scale, which is suitable for the PhD research. Social embeddedness is intrinsically linked to acceptance – these concepts are crucial to consumer engagement and successful implementation of new technologies – therefore this literature is useful in supporting the smart grid pilot and fieldwork.

Both sets of literature were examined within the context of the Australian electricity sector. As a result, the theoretical basis of the thesis refers to this context through a review of relevant Australian government and industry reports where the focus is on consumers, and issues that include new market entrants offering new services, or incumbent firms with adaptive business models, for example AEMC (2017b); AEMO (2016); AEMO&ENA (2018); ARENA (2018c, 2019a);

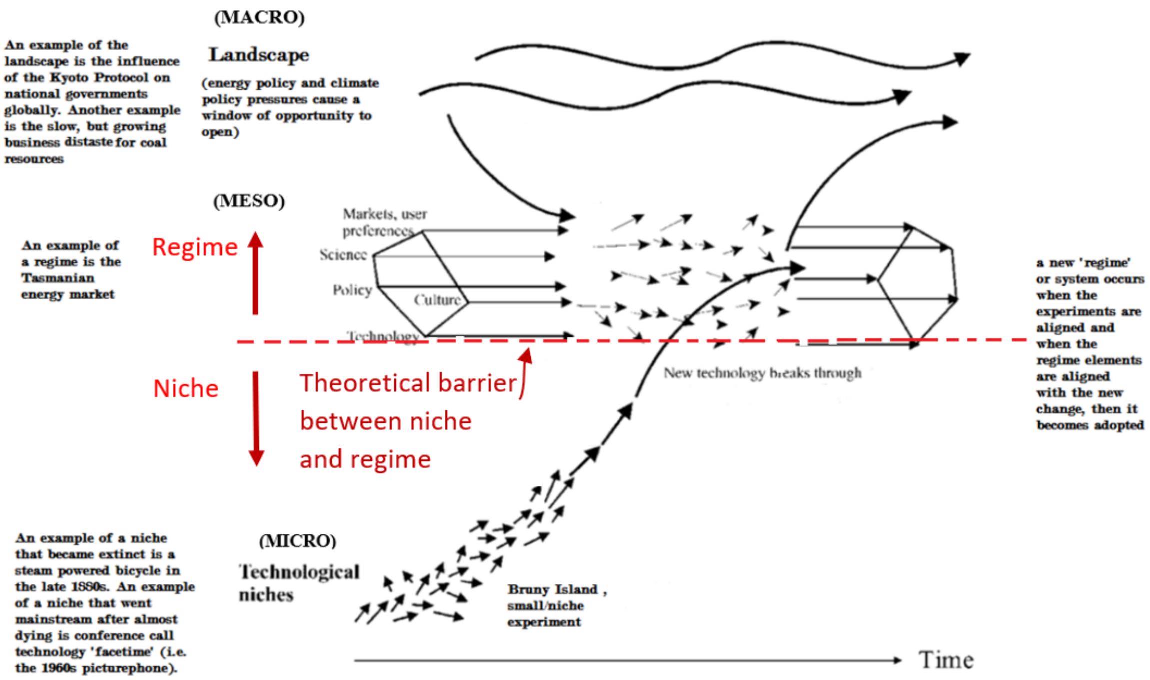
CSIRO (2014). The concept of new market entrants is highly relevant to the case study as Reposit (CONSORT project partner) is a new entrant; and similarly, incumbent firms with a vision to adapt is highly relevant to the case study where TasNetworks (CONSORT project partner) is an incumbent.

The reoccurring themes of the above cited reports relate to the thesis framework and are presented in the next section (specifically, Figures 2.3C and 2.3D).

A key example of the scholarly perspective that supports the idea of new entrants or business models solving system problems is from Hughes' book *Networks of Power*, in which he devotes a chapter to the investigation of 'reverse salients' (Hughes, 1983, Ch 4). Reverse salients are the points where systems growing fast collapse. Hughes draws on the military analogue of an advancing battle front that experiences a 'backward bulge' of weakness and collapse, at precisely the point of advancement. This analogy is applied to large technical systems undergoing rapid growth, where problems arise due to the rate of innovation. These problems in a technical sense are known as reverse salients. It seems that new entrants and new business models may be able to address the systemic reverse salients through treating the challenges to the system as new opportunities, for example, to offer grid stabilising services, where smart battery software firms may be just one example of a new entrant. Incumbents with innovative, adaptive business models might also address systemic reverse salients. The concepts of solving wicked technological reverse salients have been explored more recently than Hughes by various author including Christensen, Grossman, and Hwang (2009); and Dedehayir and Makinen (2011). Where, Dedehayir and Makinen also describe the institutional, policy and regulatory changes in conjunction to technology evolution (2011, pp.1097-1099) and the work of Christensen et al. is centred on disruptive innovation by establishing new values in business models.

The thesis now proceeds then by applying a theoretical framework as justified from the research of this chapter. As a result, a slightly different (close-up) perspective on MLP and the preconditions of innovative breakthrough to the regime level is proposed as the theoretical framework of the thesis. Specifically, the focus is on the interface between the niche and the regime level and the mechanisms that might encourage breakthrough. The MLP describes a path of technological innovation and the constellation of factors that influence regime change, but the diagram does not detail how this might occur, so this study focuses on the critical moment between the niche and the regime scale, studying the pre-conditions for innovative breakthrough to the mainstream.

Figure 2.2 below presents a modified MLP diagram, which is applied to the Bruny Island CONSORT pilot. It is proposed that the pilot is a niche-scale experiment that is initiated with regime support because the pilot is partly funded by a central government agency (ARENA) and is partly funded by an incumbent network utility. In this sense it could be envisaged that the pilot is at a precipice of innovation between the niche and the mainstream in terms of industry and technological acceptance. To further examine the boundary of innovative breakthrough and what preconditions might be, a theoretical barrier is drawn separating the niche and regime levels, as seen in Figures 2.1. and 2.2.



A dynamic multi-level perspective on transitions (After Geels, 2004).

Figure 2.2A. Modified MLP with a theoretical barrier between niche and regime representing the point of innovative breakthrough

Referencing Figure 2.2A above, and noting the theoretical barrier to system change (dotted horizontal line) this concept can now be considered not over time as in the classic MLP and transitions tradition, but rather, as a conceptual single moment in time, where the transition from niche to regime is a sudden step-change or quantum leap from one system type to another. Remaining with this concept, the four schematics below illustrate concepts of the enabling factors that might lead to innovative breakthrough. The x-axis assumes the key MLP elements of the socio-technical system under view, and the y-axis is identical to the classic MLP description of small to large scale, with the focus on just the interface between the niche level and the regime level. Importantly, the y-axis describes the enabling mechanisms to increase scale as described in the boxes below the dotted line; leading to the up-scaled outcome in the box described above the dotted lines which represent innovative breakthrough.

Theoretically, Figure 2.3A (Schematic A) below suggests a management approach to niche-projects and R&D with an approach that migrates to a systems-thinking approach as argued per Hughes (1983) for innovative breakthrough into mainstream deployment.

The enablers of innovation breakthrough described in Figure 2.3A have aspects that are steerable or influenceable.

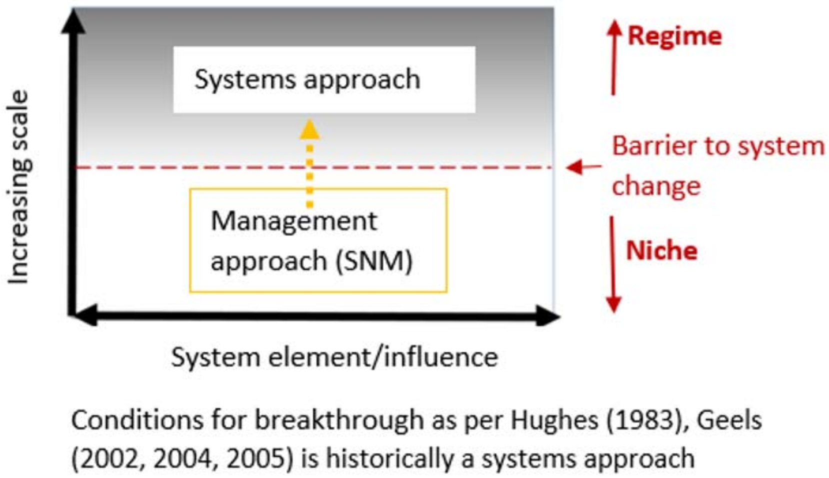


Figure 2.3A. Managing with a systems approach for innovative breakthrough, Schematic A

With regard to Figure 2.3B below (Schematic B), looking again at the theoretical barrier to system change, it is argued that the network governance and policy implementation research supports policy outcomes that have the potential to overcome the barrier of the implementation gap through connecting policy development intimately with implementation processes and actors. After the conceptual innovation breakthrough to the mainstream, policy and regulatory frameworks support the new regime configuration.

The enablers of innovation breakthrough described in Figure 2.3B have aspects that are steerable or influenceable.

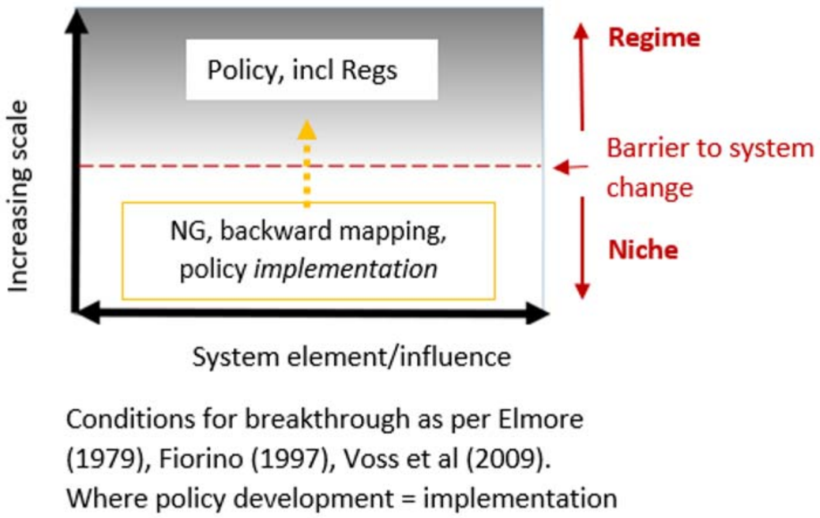


Figure 2.3B. Policy implementation and SNM as enablers of innovative breakthrough, Schematic B

Figure 2.3C below (Schematic C), describes the industry and government current understanding of 'consumers at the heart of the energy system' insofar as it has been observed and understood that consumers transitioning to prosumers are a powerful structural influence on the operation of the energy system. Consumer preferences, as seen with the uptake of solar PV, have had significant impacts on the energy system; and now there is a potential for consumer-purchased batteries to have another system-changing impact. Thus, citizens in the policy parlance, as consumers, en-masse, will potentially lead a change in the energy system through privately owned battery storage.

The enablers of innovation breakthrough described in Figure 2.3C might be considered unmanageable from a governance perspective, but may have aspects that are steerable or influenceable, through policy instruments.

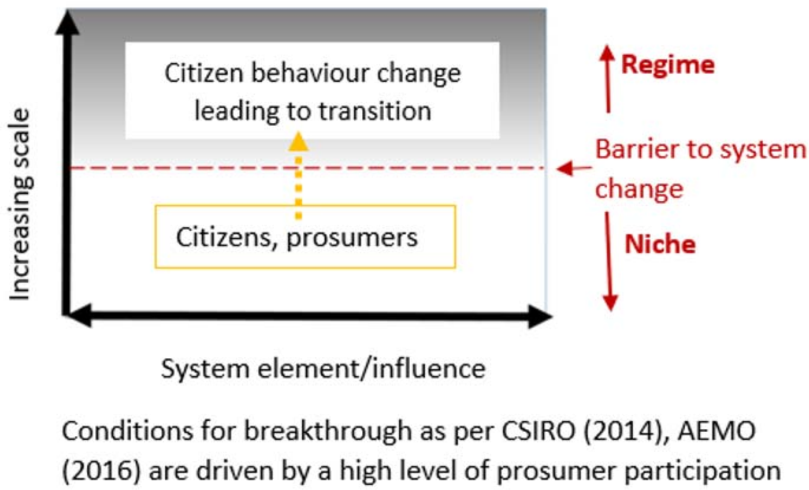
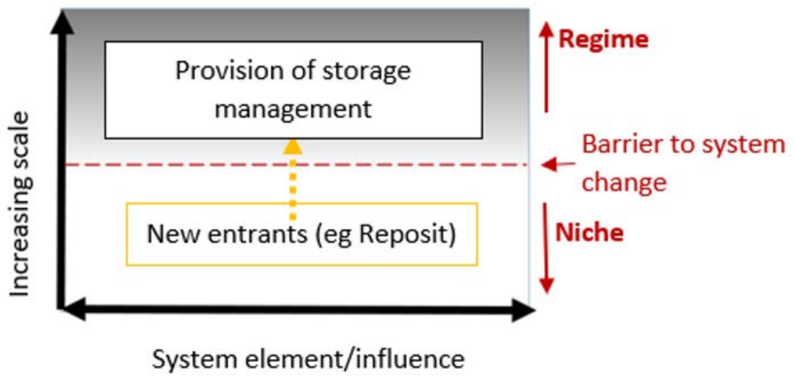


Figure 2.3C. Driven by prosumers as a condition for innovative breakthrough, Schematic C

Finally, Figure 2.3D below (Schematic D), shows the preconditions for innovative breakthrough to the regime that are supported by both STS scholars and by governmental agency reports on the impact of new entrants into the energy system and the ability of new entrants to reframe incumbent problems into new market opportunities.

The enablers of innovation breakthrough described in Figure 2.3D may be considered unmanageable from a governance perspective, but also may have aspects that are steerable or influenceable, through policy instruments.



Conditions for breakthrough as per CSIRO (2014), AEMO (2016) are driven by a high level of prosumer participation. Also solving a wicked technological reverse salient (Hughes, 1983), Christensen (1997), Dedhair (2011)

Figure 2.3D. Storage is key — new entrants solving reverse salients as an enabler of innovative breakthrough, Schematic D

The Schematics A to D comprise the theoretical basis for investigation of the CONSORT smart grid pilot. The empirical chapters Four, Five, Six and Seven all engage closely with the concepts outlined in the schematics, and a context-setting linking page is laid out directly before each of these chapters, highlighting the contribution and the link to theory.

In brief and in summary for this thesis: the case study of the PhD, the pilot, is viewed conceptually as an experimental niche and as an example of policy implementation. Using this conceptual view, research and development assists the upscaling intent of SNM, through the SNM-practices of diffusion of innovation and learning within a protected niche. This is explored in Chapter Four.

Concepts of participation, management, and acceptance are intrinsically connected with agency; and network governance is conceptually linked with *high* agency. Agency, participation and influencing factors to acceptance are explored in Chapter Five. The paper that forms Chapter Five relates to the impact of scaling-up technology whereby the driving force of scaling-up from the niche to the regime is driven by consumer preferences and consumer purchasing choices. Chapter Six focuses on decision-making typologies and the financial and non-financial aspects facing consumers, with one participant household as an example in detail.

Chapter 3 Methodology and Methods

Introductory statement

This chapter is structured into following sections: Pilot logistics and case study background (3.1); Methodological approach (3.2); and Research design and methods (3.3). The chapter concludes with a methodological discussion and reflection.

3.1 Pilot logistics and case study background

The CONSORT pilot was conducted in a rural, island context in south-eastern Tasmania, as depicted in Figure 3.1 below. The logistics of fieldwork included arranging around a ferry service that ceased operation at 6.30pm at night, with many roads on the island being dirt and the households were dispersed, and often at a distance from the ferry terminal. Bruny Island has an older demographic, with 38% of residents over 60 years of age (Kingborough Council (2017). Given the age demographic, retirees and small business owners dominated the profile of the cohort. More details on the particulars of the case are outlined in Chapter Four.

Sociologically speaking, the participants might be likened to *mainstream* Australians in relation to rates of technology adoption because the participants were not considered to be *early adopters* by the software company and CONSORT project partner, Reposit Power. Statistically, it is a reasonable assertion that the pilot participants were not early adopters. For the postcode that captures Bruny Island, the Clean Energy Council reports that there were only 93 PV and battery system installations for the period 2001-2018. However, the average number of installations (by postcode) for the rest of Australia was 730 over the same time period (CEC, 2020). In this sense, it was understood that transferable learnings might result from the pilot as a result of the difficulties working with non-early adopters, because the participants were not of the usual market for Reposit Power. It is important to note that the question of whether the pilot study learnings were transferable or not was a contentious issue among the CONSORT pilot partners. For example, Reposit Power asserted that the learnings from the pilot were not usefully transferable because the cohort demographics diverged from their usual market base (i.e. were atypical). Conversely, TasNetworks asserted that the learnings were transferable because the cohort were atypical from early adopters, and hence more like mainstream energy consumers. Transferable learning is of course important for understanding implementation and policy processes and to understand the wider implications of the case study. However, as with all case studies, the Bruny Island case study has some contextual elements that were not readily transferable. For example, the sense of community and the way information (and misinformation) was conveyed around the island (which was described during the pilot as the 'rumour mill') was an important contextual factor of the case study from a sociological perspective.

Fundamentally however, the thesis draws from a single case study, and notwithstanding the acknowledged limitations, a single case study is justifiable for transferable learnings on a methodological basis. Reasonable conditions for generalisation and inference from single case studies outlined by Evers and Wu (2006) include: 1) that there is sufficient empirical depth to the case, 2) that the case study is explained within a context, 3) that the evidence does not lend itself to a better explanation, and 4) that the evidence is data-driven. The instrumental case study of CONSORT and of the participants is asserted to fulfill these conditions so that reasonable inferences can be drawn.

The interview data for the pilot are outlined later in Table 3.3, but in brief, the CONSORT householder participant interviews (which comprised the vast majority of the interviews) either fell into 'pre-install' telephone interviews, or 'post-install' in-person interviews, on the island. Further data collection and interviews were undertaken beyond these two types of interviews (as part of the social science team), but the PhD research focuses on this data due to the intense researcher involvement during the first 2 years of data collection.

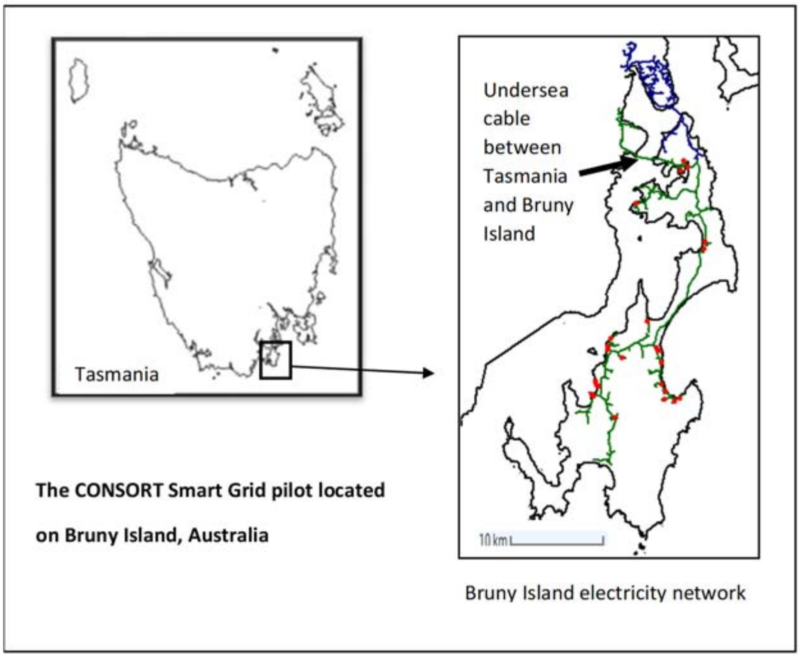


Figure 3.1. The location of the CONSORT pilot: Bruny Island, Australia

The interview types (listed in Table 3.3) were broadly aligned to the analytic perspective and themes in the thesis. Themes start at a macro-scale (systems-level) (Chapter Five) and finish at a micro (householder) scale in Chapter Seven. The scale of analysis of the empirical chapters are depicted in Figure 3.2 below, and the types of interviews were chosen to match the scale of the themes.

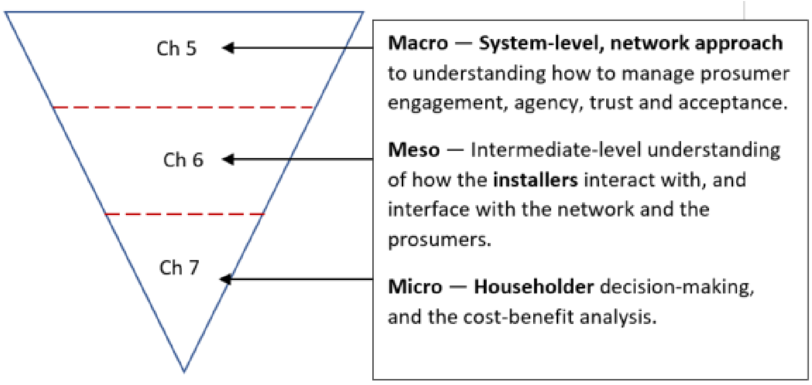


Figure 3.2. Structure and linking of empirical chapters in this thesis

3.2 Methodological approach

3.2.1 Ontological and epistemological framing

Throughout the study, in seeking answers to questions, the methods applied were those that were perceived as most suited to the CONSORT pilot as a case study under investigation. While acknowledging that 'there is no one privileged way' of deciding on methods for data collection (Walsh, 2011, p.10); the choices are justified and it is asserted that a rigour in consistency of the chosen approach is key, representing a commitment to a consistent philosophical and methodological approach to any study (Hathcoat & Meixner, 2017).

Ontologically, the CONSORT pilot can be viewed as containing elements between what is seen as objectively real — the battery software, the participants; and what is perceived as subjectively real, for example, the socially constructed knowledge by the participants in understanding how the battery software behaves. Methodologically speaking, however, the ambition was simply to apply a theoretical and methodological logic that was the most appropriately matched to the research topic.

The approach is mixed methods, that is, using both qualitative and quantitative approaches, with qualitative strategies such as ethnographic practices, and quantitative strategies such as an experiment and case study approach, where the pilot itself is an experiment.

3.2.1.1 The use of a grounded theory approach

One of the main research approaches and paradigms throughout this thesis is the consideration of a Grounded Theory Model (GTM). The concept of a GTM is an approach and way of thinking about the value of bottom-up, inductively derived data; however, it is not a standardised, formulaic approach (Morse, 2009, p.14). The term 'grounded theory' was first coined in 1967 and was described as 'simply the discovery of emerging patterns in data' (Glaser in Walsh et al., 2015, p.593). The theory emerged from a study within the health sector which looked at the existential issues of 'dying in a hospital setting' (Levers, 2013, p. 1). The GTM has been described as 'theory that is empirically grounded in data' (Walsh et al., 2015, p.582). This thesis applied this simple idea of seeking out the emerging patterns in data or information; despite some methodological research describing limitations of such an approach that seems to have an objectivist position within the health and psychology sector (West, 2001, p. 127). The case study for this thesis, with a focus on battery systems, has an inherently lower psychological risk to participants than the studies mentioned above concerning GTM, and consequently GTM is applied in a simple, practical sense in relation to an *evolving analysis of emerging themes* from interviews. Overall, for a longitudinal study — as this PhD thesis comprises, the process was iterative as described below—

> '[GTM is an] iterative process of moving back and forth between empirical data and emerging analysis [that] makes the collected data progressively more focused and the analysis successively more theoretical'
>
> (Leavy, 2014, p. 125).

Arguably this 'process of moving back and forth between empirical data and emerging analysis' is an important pattern that also closely describes 'backward mapping' — where backward mapping is an under-explored concept within the policy implementation scholarship, as outlined in the theoretical basis of this thesis, and empirically tested through the behaviour of installers in Chapter Six. It is also a possible key approach for successful policy implementation as it assists in understanding implementation issues at the small scale (including 'small scale' describing types of interactions with individual households as in the CONSORT pilot).

Grounded theory is described as a paradigm, as seen in Figure 3.3 below, and for the theoretical development of the thesis, the two main areas of theory are developed from the bottom-up (grounded — bottom-left quadrant), and top-down from more abstracted theories (top-right quadrant), though no paradigm of research was ruled out or not used to some extent within this mixed-methods approach.

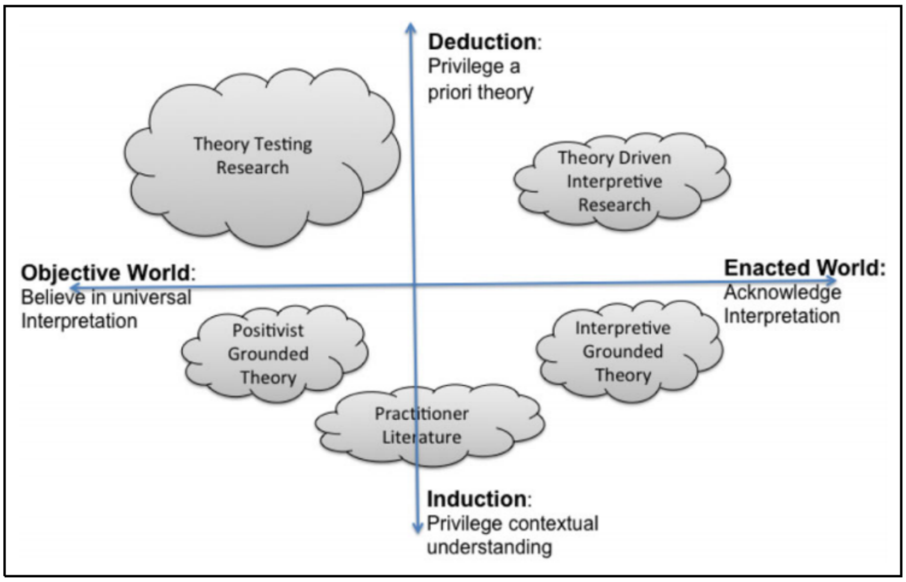


Figure 3.3 Grounded theory within the relational approach to paradigms from Levina in Walsh et al (2015)

Grounded theory is recognised as being 'closely aligned with thematic analysis' (Walter, 2013, p.327) and thematic analysis is an important method of analysis throughout the thesis. GTM was applied to the data collection where themes started to emerge and as this occurred, more theory and data collection evolved, in an inductive fashion. For example, Chapter Six focuses on the importance of the battery installers for implementation processes and is an example of where the flexibility of employing a grounded-theory approach was useful for this thesis.

3.2.1.2 The law of parsimony as a methodological lens

The concept of parsimony shares a synergy with and sits relevantly under a GTM approach; as do themes of pragmatism and heuristics as described under Epistemology in Section 3.2.2. The concept of parsimony relates to practicality and simplicity. It is posited here that goals of practicality and simplicity are aspirations for a study that cross-cuts both the social and the technical, whereby complexity is already great and where the work is partly exploratory. Increasing understanding and decreasing complexity through abstraction is desirable for understanding a relatively new area of study. The aims of practicality and simplicity are suitably applied to gaining insights to a sociotechnical experiment such as the CONSORT pilot.

Methodologically speaking, the concept of the law of parsimony (sometimes referred to as 'Ocham's razor') shares a resonance with the GTM highlighted above. Where the GTM is the discovery of emerging patterns, parsimony aims to understand the patterns without adding complexity to an already complex topic, which may render the topic opaque while it is a relatively new area of endeavour. The concept of parsimony relates to grounded theory because it simplifies and abstracts complex behaviour, relationships and patterns from data — providing an 'economy of theory' (Sober, 1981, p.146). The aim of abstraction and simplification of theory matches with the four themes of upscaling innovative technologies presented in Chapter Two, which are simplified, abstracted themes of this thesis.

3.2.2 Epistemology

In this section, heuristic and pragmatic epistemological approaches are discussed. Methodologically, the concepts of heuristics and pragmatism frame a type of approach that links the theory with the empirical in a way that accepts uncertainty.

Part of the foundation for credible knowledge-building for this thesis was based upon collecting data in a reasonable sample size to be reliable and that might extend beyond the pilot itself. The pilot was a longitudinal study over three years, with 34 householder participants; with a breadth and depth of interviews with participants that provided insight as well as a number of external interviews, including the installers, other pilot partners, researchers and others that corroborated and extended findings in key areas. In summary, no single epistemological method was employed within a mixed-methods approach. Within this thesis the theoretical and the abstract are interwoven, and using these approaches together may be referred to as 'applied rationality' (Tiles, 2013, p.319). Given the large amount of field work and that it was longitudinal, with untested technical equipment, the fieldwork elements might be described as learning-by-doing, also known as 'action research' (O'Brien, 1998, p. 2).

Knowledge is also constructed through the process of writing the thesis; through new ideas and constructed knowledge. The aim of a heuristic is to simplify, while still maintaining relevance. The CONSORT pilot is relatively large and complex; and the nature of any experiment is small and simple compared to reality and so findings are also simple by comparison to reality, and are similar to a heuristic in that sense. Additionally, there is the uncertainty associated with research, as for any experiment, findings are not known in advance, and a lack of full data necessitates a 'judgement under uncertainty' (Gigerenzer, 1991, p.83). Due to some uncertainty, and large amounts of data, a heuristic approach is seen as a useful approach 'that enable researchers to make sense of large amounts of data…[and it]…also offer[s] roadmaps for how to carry out empirical research…to better understand processes and pathways of sociotechnical change' (Sovacool & Hess, 2017, p.2). Heuristic strategies are a type of decision-making approach which was developed by the psychologists Tversky and Kahneman (1974). Heuristic strategies fit neatly in an experimental learning model because the learning is based on an experienced outcome of one form or another. Heuristics rationalise a complex problem into a simpler one, through forms of abstraction, and approximation. Heuristics 'cut the cognitive load' by employing repeated experience and judgement. Specifically, the four themes that relate to upscaling within the MLP framework that are presented as the theoretical framework of this thesis are simple and abstracted, and in this sense the theory and the case study (CONSORT pilot) are understood through a heuristic lens. Even so, cautions are noted with the overuse of heuristic devices, relating to an overconfidence in accuracy, unrealised cognitive biases, and systematic errors (Gigerenzer, 1991, pp.83-85; Sovacool & Hess, 2017, p.28).

Another methodological position, that of 'pragmatism' is considered to be relatively common within mixed-methods research and it affords creativity to researchers through 'freedom of choice…to choose the methods, techniques and procedures of research that best meet their needs and purposes...[with a keen awareness of]…social, historical, political and other contexts' (Creswell, 2009, p.11). Some theorists frame pragmatism as 'placing purposeful human activity at the heart of philosophy and science' (Allmark & Machaczek, 2018, p.1306) and the present thesis subscribes to this view. Pragmatism is described by not pre-committing 'to any one system of philosophy' (Creswell, 2009, p.10) and thus has synergies with grounded theory. In terms of CONSORT, this was the aim for understanding emerging data; although a theoretical framework was designed while data was being collected. While explaining a theory in its' simplest, most abstracted form, the thesis remains cautious about overgeneralising, which is a risk for the pragmatic approach (Sober, 1981, p.149). A learning from this approach is to maintain the aim of simplification in mind but to be wary of simplifying away the unique case study attributes.

This thesis, and the CONSORT pilot, represent a simplified imitation of reality — for example, the participants are few; only one undersea cable is considered; only one brand of software (Reposit) to coordinate the batteries is chosen; and the methodology of using interviews is limited in terms of what can be captured. Overall, the limitations and the uniqueness of the pilot are acknowledged, but there are still important elements of value for policy learning, transfer and generalisability.

3.2.3. Axiology and ethics

The concept of philosophical values in qualitative research ethics is often discussed in relation to axiology, however, in this case, the non-sensitive nature of the CONSORT pilot and the Human Ethics approvals for the study were officially 'low risk'. The participant's involvement in the social science aspect of the pilot was a mandatory component once the participant signed onto the CONSORT pilot and was approved. The participants were made aware of the uncertain outcomes that may be linked with research and the inefficiencies associated with research experiments. Focus groups and information sessions were held for interested householders before they committed to the trial, and they were not facing risks that were of a physical or financial nature. Arguably the greatest risks were emotional frustration at technology not operating as it is intended, and sometimes facing lengthy waits for resolution. These emotional effects were considerable for some participants and were under-anticipated by the research team at the beginning of the pilot.

Given an overall perspective of the pilot in retrospect, additional foresight may have improved the participants' experience; however, overall, the actual level of risk associated with inconvenience or frustration for some participants in the pilot was not considered to be 'high risk' ethically. More communication could have been provided and an 'opt out' measure may have been positive for a minority of the participant cohort. Even so, the primary consideration remains the practical consideration of ethics as a critical, protective regulatory mechanism. The Ethics Committee principles are embedded research ethics principles within this thesis, committed to them in protocol and spirit. The principles of fairness, respect, integrity and empathy are values that are implicit within the carrying out of this PhD thesis. Beyond ethical considerations, other values within the thesis are argued to be that it contributes to a growing understanding of how people adapt under technological change that might be considered to be part of sustainable transition. One of the key research values of this thesis is that it contributes to discussion on policy implementation methods and trends before mainstream deployment has occurred and when outcomes are not yet known. Underlying values here of the researcher are the belief that government, *in a networked-governance manner* with other actors comprise valuable and effective agents for change. In addition, the author's ontology is concerned with a sense of stewardship towards the environment, and a sense of responsibility for man-made influences on the environment — including adaption and transition.

The regulatory approval relates to the CONSORT ethics which covers all social science work (H0015886) and an additional PhD ethics approval (H0016022) to cover supplementary questions to householders, as well as interviews with policy experts, other researchers and the installers, which extended the range of discussion into areas that was of specific interest to the PhD, but not required as investigation by the rest of the social science team. This supplementary PhD Ethics was submitted in August 2016 and was approved in September 2016. The PhD ethics is included in Appendix A of this thesis.

The annual report was submitted as required in December 2017, and amendments to this were completed and accepted in November 2017 to allow for an additional method of 'shadowing' an installer — accompanying them on their day-to-day activities as they install or finalise commissioning of the PV-smart-battery systems. These amendments consist of an updated information sheet and updated installer-specific consent form which included a separate checklist for approval including audio recordings and photographs. These amendments reflect evolving themes of importance as the pilot unfolded and as the PhD research became more in-depth and the questions became more refined.

3.3. Research design and methods

3.3.1 Data collection, participants and sources

Methods of collecting information and evidence included a literature review and a case study. A brief methodological and data collection timeline is as follows: Year One of the PhD comprised a significant amount of fieldwork and the formation of the theoretical framework of the thesis. Preparation of the fieldwork started almost immediately with assistance provided by the PhD candidate in designing the interview schedules and topic areas as input to the social science team overall. Within three months the PhD ethics application (H0016022) had been submitted and approved. Field work spanned from December 2016 until May 2018, including both CONSORT social science team interviews and PhD-only interviews. By the Third Year, interviews had been completed (86) and analysis was ongoing or finessed as drafted chapters and papers were re-worked.

In terms of the types of qualitative methods employed, this mostly centred on the interview. There were a range of interview types, in particular: structured; semi-structured; fully exploratory; and, shadowing. Shadowing is a method borrowed from anthropological practices in the area of ethnography, where ethnography intends on a 'holistic picture of a subject of study with emphasis on portraying the everyday experiences of individuals' (Creswell, 2009, Ch9, p.196). For this thesis, shadowing was performed by accompanying the solar-battery installers and observing their activities in their work situation. To avoid repetition in this chapter, ethnography is explored in more detail in the paper that forms Chapter Five, and is not outlined in detail here. Interviews were held over the phone and face-to-face. There was also a range of expert interviews undertaken and these are outlined ahead in Table 3.3.

Method instruments for data collection and documentation included the following:

	Methods of data collection and documentation
1.	Pre-installation interview transcripts (conducted as part of the Social Science CONSORT team)
2.	Post-installation interview transcripts (conducted as part of the Social Science CONSORT team)
3.	Transcribed phone calls, notes from phone interviews, and face-to-face interviews with various stakeholders: other researchers and pilot partners; policy, government, regulatory representatives; additional pilot participant interviews; and installers.
4.	Audio recordings of installer interviews
5.	Audio recordings of regulatory expert interviews (external expert interviews)
6.	Government reports; scholarly articles; news media articles; company documents; and shared literature from other pilot partner researchers and others
7.	Emails from: the participants; installers; policy advisors; coordinators from other ARENA pilots and projects; ARENA staff and others.
8.	Data from TasNetworks, including the participant online forum hosted by TasNetworks
9.	Testing of method assumptions and sought advice from industry experts and others
10.	Shadowing — whereby the researcher accompanied two battery system installers for a day to Bruny Island. Data sources from this were field notes, observations and photographs.
11.	Interviews with participant BT112 (as part of the PhD research, beyond CONSORT)
12.	Interviews with CONSORT research partners, from TasNetworks, Reposit Power, ANU (audio recorded)

Table 3.1 Methods of data collection and documentation

Table 3.2 below highlights the chapter-by-chapter detail of the methods of data collection against the research questions.

Chapter/title	***Research Question***	***Methods***
Chapter One Introduction	***During a time of systemic disruption within the electricity sector in Australia, how might a transition to smart grids be encouraged to be accelerated and governed in an orderly manner?*** Underlying this question is: **What are the pre-conditions for innovation to breakthrough to the mainstream?**	Desktop research: referencing literature, reports, other information where required.
Chapter Two The conceptual framework for the research on the CONSORT smart grid pilot	Chapter two sets out the theoretical framework of the thesis by exploring the question set out in Chapter One above.	Conduct an international literature review of the most relevant literature and case studies of energy systems governance, innovation and SNM.
Chapter Three Methodology and methods	Present what methods/methodology have been used and why these methods were chosen. Justify the appropriateness of methods.	This is a case study approach, with a list of methods provided. The chapter outlines and justifies the approach from an ontological, epistemological and axiological perspective.
Chapter Four Strategic niche management and governance: An exploration of the CONSORT pilot	How is the CONSORT pilot governed and implemented; and what SNM-like practices and processes were used?	Interviews of pilot partners; literature reviews, and observational approaches, including media, review of the online forum for participants, and personal researcher observation.
Chapter Five The precursors of acceptance for a prosumer-led transition to a future smart grid	What are the conditions that lead to consumer acceptance of a new technology (smart batteries)? Examining acceptance from a network-level perspective, a second question is; How might the enabling conditions be related in a way that may assist utilities and prosumers to accelerate a transition?	Interviews with HH, network utility, other pilot partners, as required, from a grounded theory methodology. Observation and analysis of the case highlighted the scholarship gap.

Chapter Six. The evolving role of battery system installers within a transitioning electricity sector	The paper aims to examine how innovation intermediary roles might adapt post-disruption. The policy implementation scholarship is explored to understand the installers role in a post-disruption phase.	Interviews (including CONSORT fieldwork) plus PhD interviews of installers, and the TN engineer.
Chapter Seven Transition to decentralised storage: Consumer decision-making and cost benefit analyses	The paper centres on the concept of problem typologies (logics) in relation to consumer-decision-making as a key driver towards a sustainable transition. Specifically, the decision-making typology investigated is the cost-benefit analysis methodology. What are the CBA assumptions? Are PV-battery systems cost-effective? The analysis is linked to the complexities, gaps and tensions between householder decision-making 'values' and the gap in utility decision-making 'values.'	Draws on SS and CBA related literature, and literature on decision making. Interviews and data were provided by CONSORT pilot partners, and from participant interviews. A critique is provided of the use of the CBA as a policy decision-making tool. The CBA is applied and demonstrated; and key assumptions are explored.
Chapter Eight Discussion and Conclusions		Synthesis and conclusions

Table 3.2. The PhD thesis Research Design Table

3.3.2 Sampling, recruitment and study design

The study design of the CONSORT pilot was prescribed to a significant extent before the consideration of this thesis. Four PhD candidates contributed to the overall CONSORT pilot; two economics-based candidates from the University of Sydney, one candidate from the Australian National University focussing on the computer-science logic, and one candidate (the author) based in the social sciences from the University of Tasmania. This thesis carved out an area of social science investigation within a techno-economic pilot — that was quite apart from the technical and the economic — but contributed alongside these endeavours of understanding.

From the TasNetworks perspective

The network utility, was the central architect of the technical aspects of the design where it interfaced with the participants — in particular, the eligibility criteria for the householders (suitable internet; occupancy type such as favouring full-time residents; that the householders would choose their own installer from a TasNetworks-approved list; that they were willing to contribute a minimum $2,000 to be part of the trial). The participant contribution and ensuring participants choose an installer was seen to allow the trial to appear more 'real-world' or market-ready and, importantly, to encourage a sense of ownership by the participants. Specifically, the arrangement with ARENA provided a householder cap on the subsidy of $16,000 per PV-smart-battery system, with the minimum customer contribution set at $2,000. The calculation was based on how many batteries were estimated to be able to off-set, or nearly off-set, expensive diesel generator-use especially during tourist peaks that align with peak electricity demand. Thus, the householder interviewees selection was not statistically random, despite the successfully chosen participant names being selected randomly.

From the UTAS, social science team perspective

After the UTAS Human Ethics procedures, interviewees were recruited by contact via telephone and email, and then information sheets, indicative question sheets and consent forms were emailed to them. These interviewees consented via email or verbally which was permitted within the ethics process. The author was able to draw on the social science team data, but a PhD ethics application was lodged so that additional interviews could be conducted, and all PhD interviewees were selected (not random). These PhD-specific interviewees were either connected to the pilot or were known as experts in their respective fields.

In terms of the design of the social science research, the author contributed almost immediately to interview topics, shaping the pre-installation interview questions and fieldwork, beginning with attending, recording and transcribing an on-island focus group at three months into the PhD (September 2016).

Pre-installation interviews were focused on existing knowledge and current use of energy (UTAS Social Science Team, 2016) and the interview schedule is located as part of Appendix A, as is the post-installation interview schedule. The post-installation interviews explored

> 'the install process, your experiences with the technology so far, your experience of the electricity feedback you now receive, information you received about the technology, tariffs, network support payments and the subsidy'
>
> **(UTAS Social Science Team, 2017, p. 3)**

Overall, the author particularly supported the pilot's first two-years of UTAS research activities and aimed to stop collecting data in May 2018, to then focus on analysis specifically for the PhD. The social science team continued to finish the 'post-install' interviews, and another round of 'final' interviews as well as 'energy diaries' which the author had less involvement with. Thus, for this thesis, in terms of fieldwork, data gathering and analysis, the author decided to draw primarily from the first two-years of the pilot; although evidence was drawn from the final report on the social science of the CONSORT pilot, as reported to ARENA.

From the PhD perspective

Interestingly, the boundaries of the CONSORT social science team and the PhD contribution seemed to be unclear, at least initially. Working as part of a wider team, including the other project partners, meant that there appeared to be two streams of work and objectives — CONSORT; and the PhD — and for the first number of months this division did not appear delineated. However, through discussion at meetings with the wider social science team, the PhD research questions started to evolve, and a space was carved out and became protected for a PhD contribution. One unexpected theme that emerged early on was the importance of the installers, and this then led to a PhD Ethics amendment to incorporate the installers and a focus on the installers, which also lead to the contribution to the ARENA reports on this topic; although it still remained 'PhD work'.

Table 3.3 lists the interviews (86) that are central to the PhD thesis, where the author conducted 72 of these interviews. This does not include the Final Interviews (of approximately 30, which were almost exclusively conducted by another social science researcher on CONSORT, (Watson). The author conducted only one of the Final Interviews, in September of 2018. The interview data is tabulated below in Table 3.3. Overall, there were six types of interviews:

1. CONSORT team — **participant interviews as part of the social science team** (34 pre-installation interviews and 32 post-installation interviews as two participants did not continue with the post-installation phase, the author contributed to these as part of the team);
2. PhD-specific — **research partner interviews** [9 individuals interviewed, with the TasNetworks innovation engineer interviewed in 2016, twice in 2017 in relation to the Chapter Seven, twice in 2018 in relation to the installers (Chapter Six). The customer engagement advisor at TasNetworks was interviewed informally twice over the course of the pilot];
3. PhD-specific — **installer interviews;** Three installers, and 2 installers shadowed, totalling 5 interviews]
4. PhD-specific — **governance and policy interviews** (external to the pilot);
5. PhD-specific — **interviews of participant BT112 in greater detail** [discussed in Chapter Seven];
6. PhD-specific — **interviews for systems-context** (external to the pilot, expert interviews — policy and regulatory).

Interview data that the PhD thesis drew on

Name of interviewee	Expertise/ Organisation/ state	Date of interview/ telephone or in-person	Chapter used in	PhD-specific / CONSORT team interview/ interviewer/code
CONSORT interviews as part of the social science team				
CONSORT household participants (coded)	Householders/TAS Pre-installation phone interviews	Nov 2016 to Mar 2018/ telephone	Various [empirical chapters	As part of CONSORT SS team -BT101 – BT141
CONSORT household participants (coded)	Householders/TAS Post-installation visits	July 2017-Jan 2018/ in-person	Various [empirical chapters	As part of CONSORT SS team -BT101 – BT141
Focus Group	Focus group and information night with all participants invited	22 Sep 2016/ in-person	General background	As part of CONSORT SS team
Research partner interviews (internal to the CONSORT pilot), names removed				
Innovation engineer, TasNetworks/TAS		25 Aug 2017; 29 Aug-2017; 14 Feb 2018/ telephone	Ch5; Ch6; Ch7	PhD-specific
Smart grid research fellow(economics)/ USYD/NSW		12 Dec 2016/ telephone	Ch7	PhD-specific

		22 June 2017/ telephone		
Customer engagement specialist, TasNetworks/TAS		4 May 2017/ telephone 23 May 2017/ telephone	Ch1; Ch4 [for ERSS paper]	For ERSS paper (social science team)
Reposit Power Manager/telephone		22 Feb 2018 /telephone	Various [empirical chapters]	PhD-specific
Reposit Power Director		2-Mar-2018/ telephone	Various [empirical chapters]	PhD-specific
CONSORT Research Leader/ANU		26-Sept-2018/telephone	Ch4	PhD-specific
Innovation Team Leader/TasNetworks		10-Oct-2018/ telephone	Ch4	PhD-specific
Social Science Lead/UTAS		9-Oct-2018/ telephone	Ch4	PhD-specific
Power systems engineer, UTAS and researcher on CONSORT		26 Sept 2017 1 Aug 2018/ in-person	General/context and Ch7	PhD-specific
Installer interviews (internal to the CONSORT pilot)				
Installer A	GM of Installer business/Coded/TAS	4 Dec 2017/ telephone	Ch6	PhD-specific
Installer B	GM of Installer business/Coded/TAS	29 Nov 2017 /telephone	Ch6	PhD-specific
Installer C	GM of Installer business/Coded/TAS	28 Nov 2017/ telephone	Ch6	PhD-specific
Installers C, D	Electricians shadowed to the island	24 April 2018/ in-person	Ch6	PhD-specific
Governance and policy interviews (external to the pilot)				
Scott, John	Retired advisor to government/ACT	23 Apr 2018/ telephone	Ch1; Ch5	PhD-specific
Leitch, David	Energy Utility economist/consultant/NSW	12 Sep 2017/ telephone	Ch7	PhD-specific
Wood, Tony	Energy Program Director, Grattan Institute/VIC	6 Apr 2017/ telephone	General	PhD-specific
Gilding, Jack	EO, Tasmanian Renewable Energy Alliance/TAS	13 Sep 2017/ in-person	Ch7; (Ch5 to a lesser extent)	PhD-specific
Anonymised	Retired policy advisor in NSW/TAS governments	16 Sep 2017/ telephone	Ch1; Ch5	PhD-specific
Other residential battery trial interviews				
Newman, Andrew	Strategy Officer, Strategy and Knowledge Sharing, ARENA	24 and 25 Jan 2017/ telephone	Ch1, Ch4	PhD-specific
Swinson, Vanessa; Hamer, Joanne	Energex – Energex battery trials (Demand Management Team)	13 June 2017/ Telephone conference call	Ch4; Ch5, Ch8	PhD-specific
Stiebel, Lisa	Program coordinator, SERREE Project - Ginninderry Consumer Attitudes Study.	10 Feb 2017/ telephone	Ch1; Ch4; Ch8	PhD-specific
Cox, Jason.	Program Coordinator, Moreland Microgrid.	7 Feb 2017/ telephone	Ch1; Ch4; Ch8	PhD-specific

	Moreland Energy Foundation [virtual trial]			
Interviews for systems-context				
Negnevitsky, Michael	Power systems engineer, UTAS	9 May 2017/ in-person	General/context	PhD-specific
Jones, Laura	Innovation engineer, TasNetworks, CONSORT *	17 Jan 2017/ telephone	ERSS paper*	SS team
Bevan, Richard	Former CEO Transend	20 Apr 2017/ in-person	General/context	PhD-specific
*The 'ERSS paper' was a paper which this author contributed to as a co-author in the journal *Energy Research and Social Science*				

Table 3.3. Interview details for the thesis

3.3.3 Data analysis

Data was sorted and saved in a systematic way for both the wider-team data and for PhD-specific data. Folders of interviewee audio files, notes, references and field notes, interpretations and calculation, and other data, were kept on the researchers' laptop, and on a network drive 'the N drive' which the UTAS social science team had shared access to. CONSORT social science interviews that the PhD research drew upon (the 'pre-install' and post-install' interviews primarily), were audio-recorded and sent to a transcription service for verbatim transcription. The additional PhD-specific interviews were audio-recorded and filed, with the author extracting verbatim quotes as required. A transcription service was not used for the additional PhD interviews; these interviews had notes taken, and verbatim quotes were obtained by focusing on times in the recording that demonstrated the theme of analysis under investigation. No theme coding software was employed. Themes that arose in the early stages of the pilot were pursued (the installers in particular). Themes were analysed in alignment with the empirical chapter requirements.

The data analysis was mixed methods and mainly qualitative, with the cost-benefit analysis paper, Chapter Seven, containing more quantitative analyses than the other empirical chapters. The main type of analysis is thematic analysis (Walter, 2013, p.324), which is the categorical assignment of themes for investigation within the thesis. The logic of those categories was organised and arose from the data (grounded) as well as the theory. In general, the vast bulk of the data; transcripts and interviews were analysed and interpreted as an 'ongoing process involving continual reflection…[with]…collecting open-ended data' (Creswell, 2009, Ch9, p.184).

3.3.4 Ensuring validity and reliability

Reliability can be demonstrated through systemising the data-collection methods; (e.g. coding participants, systematic organisation of data storage) which occurred at the wider CONSORT project-team level, the social science team level and the level of PhD research. The author attended the social science team meetings (generally fortnightly, then monthly towards the end of the pilot), as well as the whole-of-team meetings ('BiCons') and being embedded within informal discussions and emails with other project partners validated a basis of the emerging findings.

Research validity was improved with triangulation, which is a form of cross-referencing that includes using different methods was used in this thesis. For example, the mix of focus groups, interviews and energy diaries used within main social science team, plus for the PhD research a CBA analysis was also conducted as well as the additional PhD interviews. 'Triangulation is the combination of two or more data sources…approaches… [or] perspectives' (Thurmond, 2001, p. 253). Where data overlapped in agreement on certain concepts, it strengthened the argument or added extra dimensions to the knowledge. Multiple methods and triangulation are ways to increase the reliability and validity of qualitative data (Mason, 2002, p.190) and they are employed through this thesis. Research validity was also upheld by ensuring suitability between the research questions and the methods; and with accurate recording of important information, including audio. As mentioned earlier, in a similar manner to wider-team data management, the PhD data was also kept to relatively systematic record-keeping for evidence that was PhD-specific. This ensured that, for example, interview notes and audio could be easily traced and checked against. The validity, and the logic of the link between the research questions and the methods, was strengthened by refining the PhD research questions to a point where the types of information and sources started to be revealed. For example, the pivotal importance of the installers as intermediaries was only revealed well after a year of research; previously there were only hints of this as a nascent theme.

3.4 Discussion and reflection

A mixed-methods approach was used for the thesis overall. This chapter has outlined the justifications for the approaches taken in this thesis. It has demonstrated the internal logic of the chosen approaches, and the consistency between the research questions, though layered, to the methods used to answer them. This chapter has outlined the positioning of the research from a grounded ontological and a pragmatic epistemological perspective. In summary, the thesis approach weaves both a higher-level theoretical approach, with a small-scale grounded approach both of which are suited to understanding the case study and building new knowledge.

Reflection on methods

The approach and method adapted over time, as might be expected, for example, the indicative (PhD-specific) questions that were designed for interviewees in 2016 were too broad to be useful by 2018. In addition, questions related to SNM, policy implementation concepts and the CONSORT pilot were included for discussion with policy expert interviewees towards the end of the data-gathering stage. Further, the questioning became more open-ended and more unstructured over time, was more adapted to the specific expertise and knowledge of interviewees and was flexible enough to be led by their previous answers in some cases. The author had observed from a previous Masters' thesis within the same discipline that greater freedom was afforded in designing relatively wide questions for the purposes of capturing the span of question types for regulatory approval, and that this could provide the flexibility to focus over time whereby the exact questions required may not be predicted two or more years in advance.

The methodology and methods are relatively conventional within this thesis; i.e. an in-depth literature review that is provided to justify the exploration and to provide a theoretical framework within the scope of an industry-PhD purpose; followed by interviews that related to the case study or the theoretical framework, or both. One slightly uncommon feature from a methods' perspective is shadowing, which was found to be valuable and is explained further in Chapter Six.

One aspect of methods that might be considered slightly unconventional and interesting to briefly reflect on was the type of interaction with some of the households during the on-location interviews. Originally, the intention of these home visits with the participant households was to observe, interview and record. The intention was not to participate in any technical discussion on the issues the householders were experiencing with a view to 'fixing' issues per se. From a methodological view, the social research was designed to be separated from the other aspects of the pilot. However, in a departure from the original intention, over time the social science team adopted an more action-research approach, because households were asking us about problems they were encountering with their technology. The social science team, this author included, responded to the issues the householders were facing by recording the issues in detail and reporting these technical issues back to the relevant members of the CONSORT team to expediate a solution, with the householder's permission. This was done to help improve the chances of success of the pilot overall. I recognise that this approach is methodologically 'untidy' and not especially common in interviews, however, being social research, a subjective, participatory approach was considered appropriate.

The author participated in problem solving with the householders at times, for example, providing a personal mobile phone to set up an internet connection (a portable mobile hotspot) in an attempt to initiate a connection with the ICT company (Reposit) to commission the battery software. When this failed the author climbed a fire truck a few metres away to see if reception could be improved at height, and also contacted a source within a telecommunications company to seek advice while with the householders. This sort of participation is not conventional and was actively intervening to expedite solutions for householders. I would suggest that this kind of participative research increased social learning of the pilot. However, it is acknowledged that it might have influenced overall pilot outcomes, and therefore the research itself.

In summary, the thesis is dominated by a qualitative-research approach and was undertaken as part of a team. The approach of this thesis, particularly because of its focus on a case study, meant that a grounded approach was favoured. This grounded approach gave rise to resonant approaches such as pragmatism, and an intuitive use of heuristics, yet maintaining a streamlined approach to the theory, similar to the Ocham's razor of shaving away unnecessary complexity. The theoretical foundation of the thesis was devised through the existing scholarship, through understanding the current system context through government and sector-specific reports and through triangulation of all the information to construct new understandings. This chapter describes not just the outline of the methodological philosophy, but also describes the methods employed, the ethics and data collection methods and how these are deployed and why they are suited to the philosophical approach of the thesis and the research questions.

A contextual lens and outline for the chapter ahead, Chapter Four

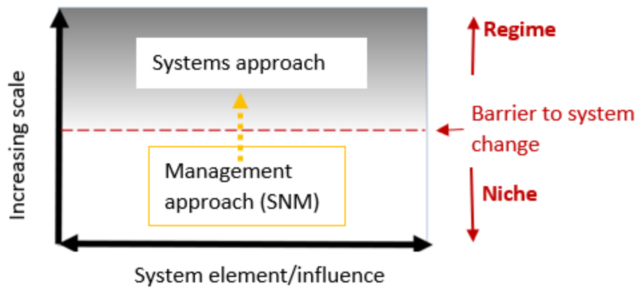
This outline is the first of four, stand-alone outlines that precede and introduce the empirical contributions of this thesis where a submitted journal paper is in the place of a chapter. The outlines provide a succinct description of each papers' theoretical relevance to the thesis, and its specific original contribution towards the thesis overall. The outlines support the overall coherence, connection and linking of the empirical papers to the thesis as a whole. In this instance, given the contribution to theory, though not submitted as a paper, Chapter Four also has an outline.

The empirical material this chapter draws from interviews with the CONSORT research team, pilot project documents, the Social Science ARENA CONSORT Final Report (2019), CONSORT whole-of-team 6-monthly meetings ('Biannual CONventions' or BiCONs), CONSORT social science team meetings and researcher observations.

This chapter engages with the overarching thesis question on the conditions needed for innovative breakthrough, which is questioned through the lens of SNM: Namely, 'How is the CONSORT pilot governed and implemented; and what SNM-like practices and processes were used?' Hence, the key relevance of the chapter is the engagement with SNM, implementation and governance. The chapter describes the pilot and provides evidence for SNM-like practices that are linked to innovation at the niche-scale. The original contribution of the chapter is the study of SNM within a contemporary (non-historical) smart grid case study contemporaneous with its implementation.

The schematics below, revisited from Chapter Two, consider transition *as if it were a conceptual moment* in time, that is; a 'before' which constitutes the *niche-scale* and an 'after' transition which constitutes the *regime-scale.* Similarly to the MLP, the y-axis is scale, and the x-axis is time. However, it is a snapshot or moment as described (so that a change over time is not represented). It is noted that transitions (up-scaling, implementation, or 'breakthrough') may take years, but this abstraction allows a close attention on the enabling conditions of a 'before' and 'after' of transition. This barrier between the niche and regime is also expressed in policy terms as the implementation gap that SNM may assist in overcoming.

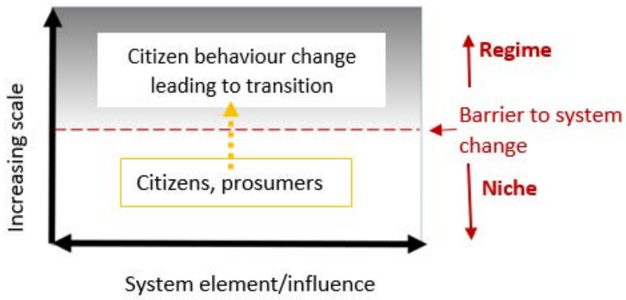
The two schematics below describe the theoretical relevance and contribution of the chapter. Chapter Four contributes an understanding on aspects of SNM and prosumers driving change as part of 'Niche conditions that contribute to innovation breakthrough – 'Schematic A'. The top diagram situates SNM as an effective set of policy practices that may lead to breakthrough. Once the system change is near breakthrough (or post-disruption and up-scaled), a 'systems thinking' approach prevails, as per Hughes (1983) description.



Conditions for breakthrough as per Hughes (1983), Geels (2002, 2004, 2005) is historically a systems approach

Niche conditions that contribute to innovation for breakthrough, Schematic A

Schematic C below simply acknowledges that potential prosumers are central to change and implementation. The pilot participants are an proxy for real-world potential prosumers. This aspect of transition is viewed as relatively ungovernable in comparison to SNM within projects, notwithstanding future, untested policies by governments and utilities targeting prosumer engagement.



Conditions for breakthrough as per CSIRO (2014), AEMO (2016) are driven by a high level of prosumer participation

Niche conditions that contribute to innovation for breakthrough, Schematic C

The CONSORT pilot aimed to understand the behaviour of future prosumers interacting with the grid. In this sense the CONSORT pilot designers were cognisant of the trend of consumers driving system transition. Therefore, Chapter Four may be viewed through the lens of SNM and citizens driving change, as key elements that may accelerate a socio-technical systems transition. In the case of the CONSORT pilot the acceleration is caused by innovative technology (internet-enabled, residential batteries). It is noted though that CONSORT participants are not ‘early adopters’ and in this sense might provide a more realistic picture of the challenging barriers to consumer acceptance and adoption more widely.

Chapter Four

Strategic niche management and governance: an exploration of the CONSORT pilot

4.1 Introduction

This chapter serves a two-fold purpose. Firstly, as a case-study chapter, and secondly, an exploration of key theoretical aspects of the thesis: SNM and governance within the pilot project. The CONSORT pilot has been outlined briefly in Chapters One and Three, but here the distinctiveness of the CONSORT pilot, as a case study, is delineated.

The distinctive feature of CONSORT, at the outset of the project was the ANU software, the NAC (Network Aware Coordination), that enables individual household batteries to respond to network events and signals rather than as a whole fleet. The CONSORT pilot also had a wider scope compared to other Australian projects, involving both a test of 'dynamic pricing, and local energy markets' (CONSORT, 2015) — that is, the pricing reflected *individual* battery operation and the potential for *local* energy markets. In this way CONSORT tested the idea that batteries can coordinate in a local response at a price that varies from the set NEM price.

However, the CONSORT project plan identified eight ARENA projects that were similar to CONSORT and were contemporaneous to CONSORT, excepting one. These are: The King Island Renewable Energy Integration Project; the Lord Howe Island Hybrid Renewable Energy System; the Flinders Island Hybrid Energy Hub; A Distributed Energy Market: Consumer and Utility Interest; and the Regulatory Requirements (completed 2013); Investigating local network charges and virtual net metering; Intelligent storage for Australia's grid; Virtual Power Station 2; and, Trialling a new residential solar PV and battery model. Of these Australian pilots, three tested utility scale-storage (rather than household-scale), one project looks at regulatory requirements, and one project studied virtual metering and local charges, and though this overlaps somewhat with CONSORT, CONSORT additionally considered the network issue of voltage control. The final projects focus on residential smart batteries (as does CONSORT), but lacking coordination. This individual battery response via the NAC is the technical reason CONSORT is distinctive from other pilots run contemporaneously with CONSORT. This difference is outlined in the schematic below (Figure 4.1), where micro-markets are enabled through the NAC software which can individually response to market signals and hence, network constraints. In the diagram on the left, the batteries are harnessed as one (bulk) fleet through an agent such as Reposit Power. On the right, the diagram shows individual battery responses, and at optimised prices, and since these prices differ, regional or micro-markets are able to be temporarily formed.

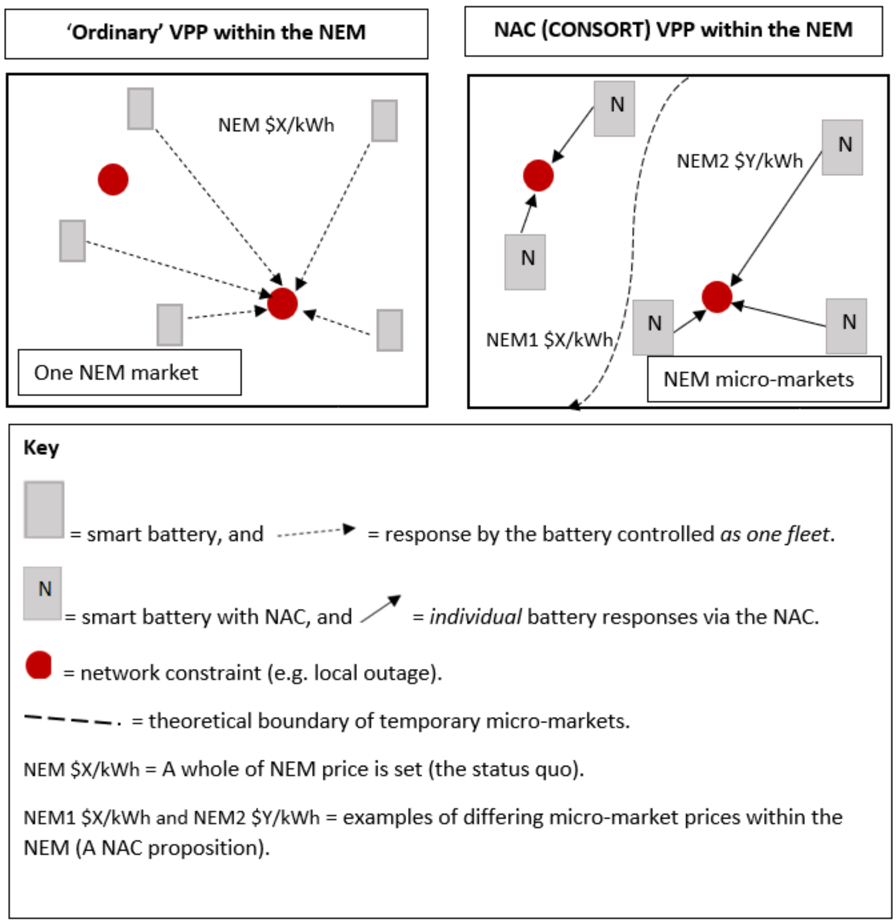


Figure 4.1. The difference between a standard NEM VPP and the CONSORT NAC VPP.

To assess how CONSORT was distinctive from a social science point of view, interviews with ARENA managers and other ARENA project coordinators was undertaken as part of the PhD investigation. It was found that across 200 ARENA projects, it was determined that CONSORT was the only one at the time with a dedicated social science team investigating the prosumer involvement in the implementation of a smart grid. The PhD investigation that makes up this thesis sits within that gap, of investigating the prosumer involvement, as opposed to engineering or economic questions.

Returning now to the more theoretical aspects of this chapter, the aim of the remainder of this chapter is to examine SNM-like practices used in the pilot. In doing so this chapter connects the pilot (as the case study), with the theoretical underpinning of the thesis in the areas of governance, policy implementation and SNM primarily through its two core sections, Section 4.3 on governance and policy implementation; and Section 4.4 on SNM. Additional methodology is discussed that frames a reflexive approach to the researchers' embeddedness within the pilot. A qualitative approach is employed for the analysis, comprising interview data from CONSORT researchers, textual analysis of the project documents and policies, analysis of how the pilot fits within the wider scheme of ARENA, and data from observations as a PhD-research participant embedded within the pilot.

Chapter Two established the CONSORT pilot as a niche-scale, socio-technical experiment, and it also examined it through the lens of the mechanisms of governance and management. Strategic Niche Management (SNM) theory is related to the case study, illuminating potentially effective management practices in upscaling niches: this is important in understanding the upscaling of niches; accelerated transition; and support for innovative technologies, which is central to the thesis. There is a bridge that connects SNM and policy implementation: the common ground between SNM and policy implementation is that they are both a form of *intervention* with a directive and a vision. SNM and policy implementation scholarship both have significant real-world application, in that they are action-based and outcomes-focussed. Arguably the most significant, practice-focused, collaborative research on SNM was published in 2006 (Mourik & Raven, 2006) in a report that outlined future policy instrumentation of SNM. This report pragmatically engaged with the concepts of SNM as having practical 'toolkit' applicability for upscaling niches (Mourik & Raven, 2006 p.32). It was hoped that SNM would be an implementable policy tool aimed at project managers 'who aim at orchestrating the interaction between multiple experiments' (Mourik & Raven, 2006, p. 2). So the aim in this chapter; establishing the presence of SNM-like practices within CONSORT, is inspired by the work of the above mentioned report — that there may be elements of SNM that may be useful as a guide, prescriptively; noting however, the fuzziness and complexity of SNM processes, that SNM is not yet employed as a policy tool, and may never be so due to the ill-defined boundaries of responsibilities that comprise the key elements of SNM, and the fact that SNM processes seem to be only observed as active in retrospect.

The main research question of this chapter is 'How is the CONSORT pilot governed and implemented; and what SNM-like practices and processes were used?' To answer this, the question was streamlined into three aims; 1) to understand how the pilot was being governed, 2) to understand what governance and policy mechanisms were in place, both explicitly and implicitly within CONSORT, and 3) to identify what SNM processes were being used within the pilot.

With reference to the above statement of aims, the meaning of governance, types of policies and approach of the chapter are now specified. For the purposes of this chapter, the term governance (for the pilot) is applied as an explicit, official set of agreed interactions and policies; and the term network governance is applied as implicit, unofficial, agreed intra-project practices. Intra-project practices were captured through the author's position on the project using ethnographic methods (as one of the mixed methods used for this chapter). The ethnographic methods used are explained further in Section 4.2 below.

The notion of network governance and SNM is of theoretical importance in this thesis and is analysed in this chapter as reaching beyond the CONSORT pilot boundaries: to interactions with other projects, people and organisations, as is the norm for both network governance and SNM behaviour. Network governance, it is argued in this chapter, may assist in creating enabling conditions for the emergence of SNM. As discussed in Chapter Two, SNM has been demonstrated as a key enabler for scaling-up and for successful deployment, or implementation, of innovative technologies. Another contribution of this chapter, and this thesis, is the study of SNM practices in a contemporary case study, during a time of transition, whereas SNM is traditionally investigated in retrospective analyses or as theoretical reviews (Lopolito et al., 2013; Mourik & Raven, 2006; Roberts & Geels, 2019; Schot & Geels, 2008). By studying a contemporary case of a pilot from the inside during implementation, it was hoped the understanding of SNM-like practices could be further developed.

Concepts of implementation are central to this thesis and are engaged with in this chapter. As discussed in the theoretical grounding of the thesis, in Chapter Two, the concept of an implementation gap is a focus, within the context of barriers to upscaling niches and accelerating sustainable transitions. From a governance and policy implementation perspective this pilot might be likened to the analysis of a large-scale 'implementation gap' whereby smart grid technology implementation does not go exactly to plan.

The problem of closing the implementation gap during socio-technical systems transitions processes is described in Chapter One and Chapter Two of this thesis. Placing people — termed variously as end-users; energy consumers, prosumers, citizens, householders or participants — centrally to energy system transition (or a pilot in this case), is argued here as a key to tackling the implementation gap. The CONSORT pilot ostensibly places customers central to the investigation of the pilot. This framing, of the importance of the prosumers in successful implementation, is widely acknowledged with governments and actors within centralised electricity systems that now 'place consumers at the heart of the energy system,' (BIEE, 2018). This shift is also seen in government reports, and policy strategies (Finkel et al., 2017). Yet, there still appears to be a large gap between this relatively new customer-centric framing and the actual implementation of new systems, and of regulatory and policy structures and practices. Examples of this gap are provided later in the chapter. This chapter acknowledges the backdrop of this policy environment where there is a growing understanding of the importance of the householders as end-users of technology as part of the implementation gap.

4.2 Methods of data collection for this chapter

This chapter employs qualitative, mixed-methods. The methods used are a case study approach, interviews and a project ethnographic approach. Details of methods used were listed in Chapter Three, Table 3.1 and Table 3.2. However, methods and data collected for this chapter are detailed further in Table 4.1 below, because the use of an ethnographic approach only occurs in this chapter. Ethnographic techniques were chosen as part of the mixed methods for this chapter because they allowed otherwise inaccessible data to be captured. By applying an ethnographic approach the author, (as an embedded member in the pilot) was able to capture additional insights that could only be accessed by being present day-to-day as the pilot unfolded.

In terms of ethnography, the literature on business and management ethnography supported the strategic usefulness of an 'insiders point of view' (Anderson, 2009; Hoey, 2018; Roller & Lavrakas, 2015, p.178). The insider point of view in business and management literature is used to better understand consumers, consumer preferences and new markets —this is aligned to the CONSORT pilot and SNM because both are project-management related in terms of understanding implementation practices. Business (or corporate) ethnography has been employed since at least the 1990s, with cases of ethnographic-focused business units being formed (Anderson, 2009). An ethnographic approach allows, for example, further understanding of technology uses within organisations that are geographic multi-sited with virtual/digital features (Akemu & Abdelnour, 2018); and consideration of technology use *away from work*, and pertinently, *within the home* (Fitzgerald, 2005) as a relatively new development. The successful and growing application of ethnographic techniques in technology studies supports the application here, in understanding a socio-technical pilot that has a residential, energy consumer participants at its centre.

In general, ethnography allows for an in-depth or thick analysis, from an insider's view, by an active researcher. In the case of the CONSORT pilot, the concept of ethnography provided value, allowing the capture of extra detail not be publicly available or accessible due to micro-political, commercial, or other reasons affecting CONSORT partners. A partly ethnographic approach meant that unofficial, implicit governance (rules and interactions) could be explored in addition to formal evidence and data. Secondly, from a theoretical perspective, SNM processes are not documented within the pilot (except for this thesis), even though they are known as vital for upscaling, and are often implicit; so, ethnography is a suitable description as an approach for uncovering this implicit

SNM data. It is noted here that the CONSORT team did not set out to follow SNM-like practices and were not aware of SNM at the outset. Thus, the exploration of SNM in this context is implicit, except where interviews directly discuss SNM. As a researcher employing a partly ethnographic approach then, the author has been able to look out for, ad make explicit, the use of SNM practices during the pilot.

The types of data collection that form the evidence and the basis of this chapter, cited briefly in the methods chapter, Chapter Three, are outlined fully in Table 4.1 below.

Sources of data for Chapter Four.	
Source of evidence	**Collected as part of the Social Science CONSORT team, or individually as PhD research**
The researcher's experience of the 3-year pilot; engaging with SNM literature, ethnographic methods literature.	PhD only, comprising the partly ethnographic perspective.
Interviews of key pilot partners (generally research or pilot leader; the interviews span structured to unstructured types.	PhD research only.
Interviews of householders. Observations at the participants' homes.	PhD observations as part of a CONSORT team effort.
CONSORT pilot project documents; Government reports, and other reports and scholarly works.	PhD only. Non-government reports were documents produced by CONSORT team members or ARENA.
The Bruny Island Battery Trial 'participants' forum' posts.	PhD research only, analysing CONSORT data and team interactions with participants via a forum.
ARENA-CONSORT milestone reports.	PhD research as analysis of the reports produced by the whole CONSORT team.

Table 4.1. Specific sources of data for the CONSORT case study chapter

The author made contact with an ARENA Strategy Officer to discuss types of ARENA projects (Newman, 2017), and through this process, the coordinators of projects that were identified as most similar to CONSORT were interviewed (Cox, 2017; Stiebel, 2017; Swinson & Hamer, 2018). The author did not find other ARENA pilots that describe the internal implementation processes of an Australian pilot. The significance of this relates to the scale of socio-technical change that ARENA is supporting by dollar value and by number of projects, and the lack of data in terms of what goes on internally with those projects as they roll out. Project milestones are met (or re-negotiated) but processes on how this happens does not appear relevant to ARENA; but this is of interest here, because questioning how something happens provides a valuable data on its wider implementability.

In the next section, the theme of governance and the theme of policy implementation are analysed in relation to the pilot. First, the findings related to the *governance* of the pilot are outlined through the official and documented data sources. Then, SNM is explored in terms of how it is observed in the pilot and include unofficial, ethnographic data.

That is, the next section covers the governance structures affecting the pilot from ARENA down (larger-scale), so that the following section can then have a context to discuss SNM (smaller-scale interaction).

4.3 Concepts relating to governance and policy implementation within CONSORT

This section presents an outline of the regulatory, governance and policy context for the CONSORT pilot. Three main areas of policy influence were identified by the author through analysis regarding the CONSORT pilot and are presented in Table 4.2 below. Table 4.2 briefly outlines the three levels of policy interaction, in particular: from the micro (intra-organisational policies) representing a sub-niche scale interaction; to policies devised at the CONSORT/project-level (inter-organisational policies) representing niche and new entrant interaction; and policies at the ARENA level (commonwealth government policy) which represents regime and incumbent-scale interaction. This table was compiled because it provides a clear overall map of the scales of policy and governance and allows further understanding of where SNM practices appear. This structure based on scale arcs back to the concept of innovation breakthrough and the implementation gap which is an underlying theme of the thesis (small scale innovation to large-scale implementation).

This table supports later discussion in the chapter. It is argued that SNM can cut across all these scales of interaction. For example, ARENA employ policies and processes that appear to share commonalities to SNM. For example, ARENA directs all projects to comply with knowledge-sharing activities; and the CONSORT pilot as a whole and individual partners also employ SNM practices as outlined later in this chapter.

A consistency in approach (deliberate policies or strategies) between the levels should act as a check of the internal validity of CONSORT processes, management and policy against higher level directives. In other words, where actions at a project-scale are aligned with intentions at a larger-scale, implementation (upscaling) is argued to have greater chances of success.

Levels of policy interaction identified as influencing the CONSORT project			
Level of interaction	**Description and purpose**	**Example of action at this governance-policy scale**	**Scope of discussion within this chapter**
Internal ***(micro or project level)***	***Intra-pilot policy*** This policy suite consists of internal policy for engaging with the project, *within* each organisation (i.e. the policy effect is internal, and consideration of other parties is incidental).	UTAS would carry out a Human Ethics application, which is quite a lengthy legal procedure, regardless of whether other pilot partners agreed with that process or not.	A discussion of the internal organisational policies is not within the scope of this chapter because discussion focuses on examples within the social science team team, not all CONSORT partners. For governance examples at this scale, refer to Sub-sections 4.3.2., 4.3.3. and for SNM examples see Section 4.4.
Inter-organisational policies	***Inter-organisational policy*** These policies were negotiated at points at the start of the pilot.	Examples of negotiations that became policies within the pilot include IP, knowledge sharing, and risk management, which became refined over time and more focused on the consumer and installer. This	This area is a focus of this chapter because it lends itself to the

(niche and new entrant level)		could be described as a form of 'way finding' policy within predefined structures; and it exists at the interface and interaction between organisations, where new policies formed collaboratively in order for the pilot to proceed with a high level of agreement.	investigation of SNM as a set of practices. For governance examples at this scale, Refer to Sub-sections 4.3.2, 4.3.3. For SNM examples see Section 4.4.
High-level; ARENA ***(regime and incumbent level)***	***ARENA policy*** As the main pilot project funder, whereby policy relates to the ARENA *objectives*.	These objectives include: the criteria for funding successful projects, which refines the pilot scope; the 6-monthly milestone requirements once projects or pilots are successfully funded; and other areas not discussed in further detail, such as the requirement for consistent public-relations messages that acknowledge ARENA as the funder on any project publications or media.	This area is analysed in this chapter as context for the guidelines within which CONSORT acts. For governance examples at this scale, Refer to Sub-sections 4.3.1. and 4.3.2.

Table 4.2. Levels of policy interaction identified as influencing the CONSORT pilot

Using the scales set up in Table 4.2 above, analysis is now directed on the large-scale (ARENA), and the policy indicator known as The Technology Readiness Level (TRL).The ARENA Technology Readiness Level is discussed because it is framed here as a deliberate strategy for accelerating innovation; and moreover, as a policy method that actually *measures* niche evolution (on a scale) — at the commonwealth government level, but applied by individual ARENA projects such as CONSORT.

4.3.1 Interaction of ARENA policy with CONSORT — The Technology Readiness Level (TRL) criteria

In 2017, a significant energy storage report was produced by ACOLA, the Australian Council of Learned Academies, in conjunction with the Office of the Chief Scientist. The report recognised Australia's position as an 'early market "test bed" for batteries' (ACOLA, 2017, p.65) indicating that at the highest level of regulatory policy influence, they were supporting battery technology innovation. The report pointed to *Technology Readiness Levels* (TRL) as the benchmark for assigning storage technologies a stage of development, and indeed, ARENA employs this particular measure as a policy and requires prospective projects or pilots to provide to ARENA an estimated, self-assigned TRL as part of the application process and criteria. CONSORT was required, under the governance structure of ARENA, to provide a self-assessment of a TRL of the project in order to be eligible for assessment.

This TRL is a foundational policy and assessment tool for technology R&D projects such as CONSORT and is explained in a little more detail below. The 'Technology Readiness Level' (TRL) is a rating scale of the emerging renewable technology that is included in potential ARENA proposals, 'measured against a suitable internationally accepted readiness scale determined by the applicant' (ARENA, 2015a); where these range from TRL1 (blue sky) to TRL9 (system demonstration) (ARENA, 2014). The CONSORT pilot self-assigned a score of TLR3 when it was applying to ARENA. CONSORT's TRL3 would sit at an early stage, as seen in the diagram below, Figure 4.2.

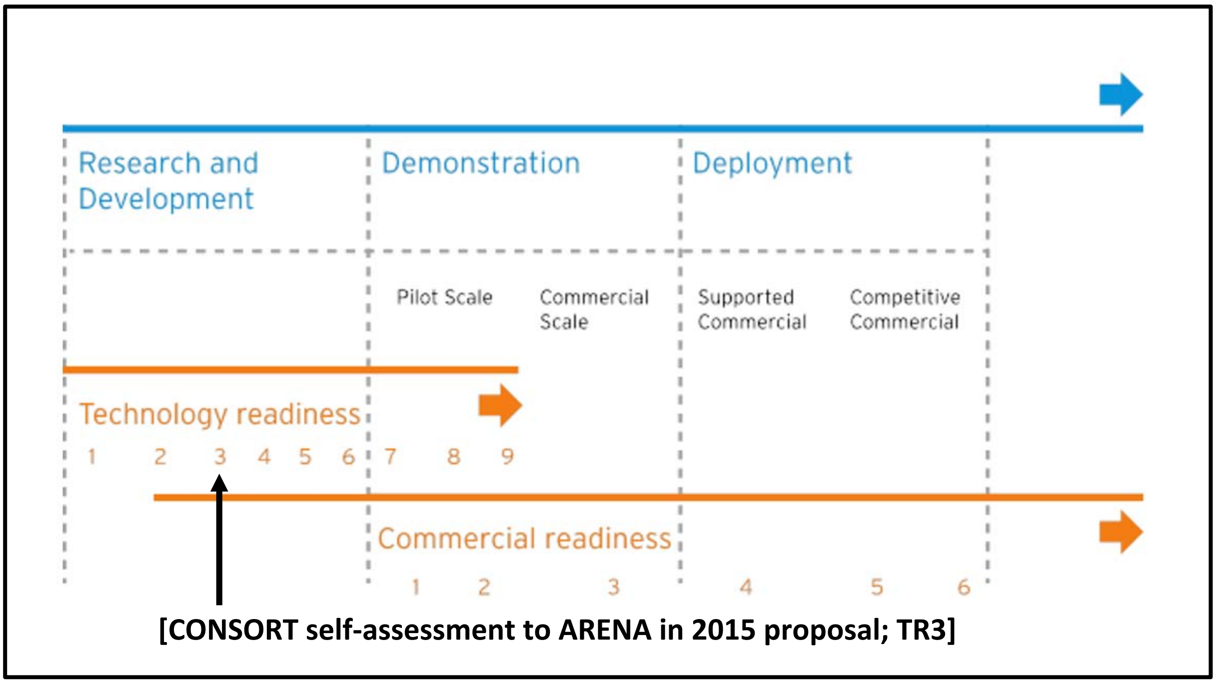


Figure 4.2. TRL and CRI mapped on the Technology Development Chain (from ARENA 2014, p. 3)

Assuming technological and research advancement during the pilot implementation, there was the ambition or 'vision that CONSORT pilot will move' up from TRL3 to TRL6 or 7 by the end of the 3-year trial (CONSORT, 2015c, p.11), representing a jump from conceptual feasibility to full demonstration (ACOLA, 2017). Jumps along the TRL scale can be seen in socio-technical terms as movements of niche projects towards the mainstream (regime), where TRL is commercial and operational deployment, which can be likened to the step before mainstream deployment.

Thus, the TRL policy device employed by ARENA is an attempt to understand both where deployment stands and predict how far a project promises to evolve along the spectrum from niche to regime with ARENA funding. It is noted that the government agency does not employ the socio-technical systems *terminology*, but regardless, the aim of an accelerated sustainable transition is identical — to accelerate innovation. That is, ARENA provides technologically neutral support for innovations that may assist a trend towards grid stability and higher penetration of renewables, among other standard energy policy objectives. The end-point of understanding such a transition is to also understand implementation, which is also a focus of this chapter, indeed this thesis.

In the case of CONSORT, much of the technical implementation success related to testing energy trading software at the utility scale (The NAC – Network Aware Coordination) in an environment that was non-virtual, with real households and conditions as opposed to hypothetical modelled conditions. In advancing CONSORT on the TRL scale, and looking to future commercialisation —

> 'Reposit's GridCredits technology is an example of an emerging category of software called Energy Management Systems (EMS). The GridCredits platform is the most advanced in the world at allowing prosumer-owned energy systems to simultaneously participate in several markets including energy, network support, and ancillary services. But whilst GridCredits can respond to market prices, it does not set prices. CONSORT is a means of calculating that price' (CONSORT, 2015a, p.9).

Some background to the structure of the NEM is now provided and then how the CONSORT CONSORT pilot research and current NEM regulatory barriers overlap. First, the NEM regions operate in alignment with the states, that is, New South Wales, the Australian Capital Territory, Queensland, South Australia, Victoria and Tasmania. The NEM does not include the Northern Territory or Western Australia and has operated as a wholesale spot market since 1998. The NEM comprises both the physical infrastructure, as well as the market (AEMO, 2018). Three agencies manage the NEM from an economic, technical and governance perspective. The AER covers economic regulation, the AEMO covers the technical operation and the AEMC has market oversight (EBS, 2018, p. 16). Further, in 2017, the Energy Security Board (ESB) was created 'to support the transition of Australian energy markets in the context of technological change…[and] has responsibility for the implementation of recommendations from the Finkel Review (EBS, 2018, p.17).

Generators traditionally participate in the NEM with respect to responding to prices within the NEM, with NEM spot prices changing every half an hour, and differ by each region (by state). A separate market for ancillary services also exists, this covers technical aspects of the power system such as frequency and voltage control (AEMO, 2015; NERA Economic Consulting, 2007). Frequency Control Ancillary Services (FCAS) are not yet regulated for residential consumers to participate in the market and provide support for the grid from their batteries. However, the CONSORT pilot is instructive for possible regulatory changes in this regard, even though the regulatory allowances do not yet exist. '*DNSPs, in particular, and utilities more broadly, often run Distribution Management Systems (DMS) and Demand Response Management Systems (DRMS) to manage and coordinate network assets, although no existing DMS/DRMS have the capabilities that will be developed through the CONSORT project'* (CONSORT, 2015, p.9).

Hence, CONSORT project plan document cited above is ostensibly stating that a (software) mechanism that sets prices is *paradigm-shifting for the industry*, because it can then create regional markets or micro-markets with different prices across the National Energy Market (NEM); meaning that the NEM does not have one homogenous price but where regions have different prices depending on constraints and responses by batteries to those constraints. CONSORT (through the NAC) provides a means of calculating a price-response for individual, privately owned batteries. The idea is that the coordination and use of NAC would enhance the influence of consumers (as active prosumers), centrally to the transition — due to the ability *individually-managed control* of their batteries.

Therefore, the pilot is positioned as being unique in its intelligent individual battery price-setting algorithms (software), but it is also unique for the significance of the social science research capabilities which have a focus on the technology's *end-users*. Both the individual battery price-setting and the social research focus on the end-users, thus, are important to understanding *actual* implementation which is examined in greater detail in the next sub-section.

4.3.2 Focus on end-users of technology and of policy implementation

The concept of the drivers of the '*end-users*' of technology is central from a government perspective of transition, but the terminology relating to energy end-users varies depending on the perspective. This thesis applies the term *participant* or householder in relation to the case study of the CONSORT pilot from the social science perspective; yet from a theoretical policy perspective the term for end-users is *citizen*, and from the energy market perspective (and by the network utility and ICT company CONSORT pilot partners) is *energy consumers*. Regardless of the terminology it is well established that these end-users within the NEM are recognised as driving change (ECA, 2018; Finkel et al., 2017; IRENA et al., 2018).

It was communicated through the CONSORT project documents and was observed through the social science research conducted as part of a team that indeed, end-users are important, and deployment of a new technology is dependent on the end-users. To accelerate transition; to overcome the implementation gap, and to facilitate an innovative upscaling (breakthrough) of a new technology; it is argued that *end-users and technology acceptance are pivotal*, and this is discussed later, as it is the core focus of Chapter Five.

Over the life of ARENA planned to the end of 2020, the agency has dedicated approximately two billion Australian dollars towards approximately 200 pilots/projects (ARENA, 2013). Eventually, pilots that are successfully deployed, as part of the energy sector transition, will of course affect and impact *people.* Moreover, it is people that are envisaged as being key to driving change, or not, through consumer preferences, hence the social implications of change are acknowledged at a high level. Despite this, investment in the social research aspects of these ARENA socio-technical projects has been relatively uncommon within the technical trials (Newman, 2017).

In terms of the theory, the end-users of a technology (i.e. citizens or actors) are acknowledged within network governance, because the web of influence extends to those that may appear to have limited official power. Network governance and SNM theories have some natural similarities — both involve people, networking, an architecture of knowledge and communications. However, the networked structure may be similar, but the scale differs, where conceptually SNM is small-scale (specifically, niche-scale) and network governance is generally described as larger-scale.

The end-user focus of CONSORT was strong yet did not appear to be the norm in other ARENA socio-technical projects, despite the current 'consumer at the heart of the energy system' rhetoric (BIEE, 2018). To test this, as mentioned, the author contacted an ARENA Strategy Officer to assess and delineate the social science aspects that were unique to CONSORT compared to other technical trials that had a social science component (Newman, 2017). The ARENA strategy officer was also not aware of any other live technical roll-out with a dedicated social science team, but provided details of three projects that were thought to be 'relevant from a social science impact analysis' (Newman, 2017) to contact by way of a follow-up. Two of the three project managers were contacted (one initiative was an ecovillage rather than a research investigation) and were interviewed (Cox, 2017; Stiebel, 2017). As a result, as far as could be reasonably determined, CONSORT appeared at the time to be the singular ARENA pilot with a dedicated social science team on live (real-world) technical roll-out, with in depth social research explorations. In that sense the pilot was unique given the depth and breadth of the social science research on the CONSORT pilot. However, of course there were various Distributed Energy Resource (DER) projects more widely, with interdisciplinary teams that include social science research, for example the Australian project testing 15 batteries, funded by the Queensland-based utility Energex (Energex, 2017b; Swinson & Hamer, 2018)

Indeed, the focus on end-users is demonstrated by the philosophy of the CONSORT algorithms, which take into account individual consumer preferences. As described by the ANU team — 'What is required is the coordination of many thousands of self-interested agents with private information in an uncertain environment, such that the result minimizes costs and preserves network capacity and voltage constraints' (CONSORT 2015c, p.10). In this regard, CONSORT is concerned with 'scalability…agency and privacy…[with respect to] prosumers' (CONSORT, 2015c, pp.10-11). 'At its completion, CONSORT will have demonstrated how Networks and Prosumers can solve network constraints, enable more renewables and be *fairly* rewarded for their efforts'

(CONSORT, 2015a, p.4 italics added). Part of this idea of fairness concerns the reality of 'customer involvement' or how real people might respond, and if they would accept and adopt the new technology. In terms of including the social sciences, and the link to understanding people and adoption, the CONSORT pilot chief investigator stated that *'it made the project much more compelling. People could see it was really closing the loop'* (CONSORT Research Lead, 2018). This is because CONSORT 'recognises that customer engagement is one of the most important considerations in the success of this project' (CONSORT, 2015d, p.16) and that there is a clear 'need to understand the relationships between people and technology (CONSORT, 2017, p.20).

The vital importance of implementation (as it relates to upscaling) and of the understanding and involvement of end-users has been outlined. The next sub-section covers management of the pilot, the project governance structure, and examples of social science implementation activities. This leads to Section 4.4, is on SNM in relation to the pilot — the largely implicit and unofficial mechanisms aimed at upscaling.

Governance and management are larger-order concepts and are official mechanisms that house any ability for SNM to take shape, so these are dealt with first, in sub-section 4.3.3.

4.3.3 Governance and management within the pilot

From the point of view of project-management responsibilities, several documents were under rapid development during the application process and these required robust and comprehensive compliance (or internal policy agreement) and a lot of combined effort from the CONSORT team to develop— as evidenced by the following core CONSORT project documents: The Intellectual Property Management Plan, Risk Management Plan, Compliance Table, Knowledge Sharing Plan, Budget Sheet, WHSE Management Plan, and the Project Plan (the Project Plan was the whole-of-pilot overview and expected timeline). The CONSORT team management (research leads) considered the roles, structure, responsibilities, meetings, and stakeholder management, and sought input from other researchers on this as the pilot evolved (through BiCons and other meetings, decisions and choices were decided on). In terms of the technical design and methodology of the pilot, four 'workpackages' (WP) were devised when the pilot initially started an committed to throughout; namely —

'WP 1: Testbed and Baseline Solution Setup; *[all disciplinary teams contribute]*

WP 2: Network-Aware Coordination; *[ICT, power systems engineering]*

WP 3: Reward Structures and Preferences; *[grid economics with some external input]*

WP 4: Network and Consumer Benefit Evaluation *[all teams contribute]*'

(CONSORT, 2015a, p.10, bracketed italics are added to delineate responsibilities).

There was reliance on the social research team to undertake the end-user related research. The agreement was that the UTAS social science team would investigate the social acceptance of the technology in WP1 and 4. Specifically this was to investigate householders' use of the real-time feed of information; the decisions made in relation to this information; and, more general responses to the user interface and associated technology. The research for workpackage 4 targeted understanding the end-user and, for the social research in the workpackage, asked: *'How do householders respond to the user interface and what actions do they take?'* (CONSORT, 2015a, p.15). The timeline and deliverables, before the official pilot commencement from December 2015–Feb 2016 included: Hazard and operability study (HAZOPS, mainly TasNetworks compliance); the formulation of the customer engagement plan; UTAS Ethics; installer selection; incentive design; customer selection; selection criteria for installers and EOI for customers (CONSORT, 2015a, p.15).

Workpackage 4 was led by TasNetworks and UTAS and was consumer-focused. It contained significant social science research component designed to —

> 'conduct in-depth empirical research aimed at understanding the households responses to the installed technology (battery and PV) as well as the new energy pricing arrangements enabled by the algorithms. Such research requires qualitative techniques, including: longitudinal in-person semi-structured interviews with householders'

(CONSORT 2015a, p.12-14).

The intention for the CONSORT pilot to pay deliberate attention to customer engagement during the entire pilot was evidenced in numerous ways. Examples include; a customer engagement plan created by TasNetworks (TasNetworks, 2016); the social science presentations to the CONSORT team that overlapped with other workpackages and discussed householders (such as issues with tariffs) (Social Researcher, 2018c); and meeting notes that documented discussion from the engineering and utility presentations to whole-of-team meetings that includes how customers were 'reacting', and how to implement 'customer messaging' (Social Researcher, 2018a).

Moving now from the discussion of pilot partners, responsibilities and the particular social science emphasis in the project, to the CONSORT team structure. This structure outlines the *governance aspects* of the pilot. This hierarchy — of the CONSORT project team, was set out in the CONSORT Project Plan, and is reproduced below in Figure 4.3.

Governance: pilot team structure

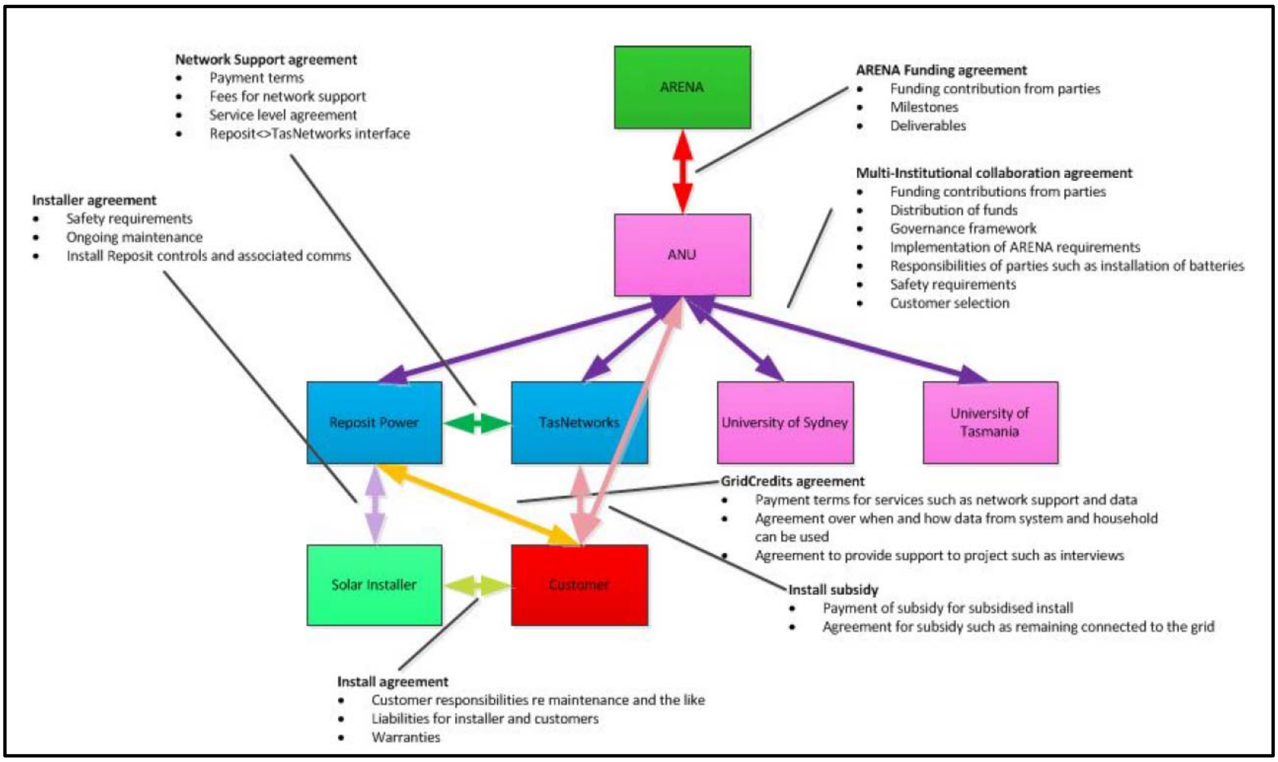


Figure 4.3. CONSORT team structure (from CONSORT, 2015a, p. 26)

In terms of project management and given the complexity of the team (multiple institutions, states, and disciplines), CONSORT adopted management that had to span multiple levels (in terms of scale). TasNetworks had a project manager to oversee the PV-battery implementation, a CONSORT pilot coordinator to report to ARENA, and a research steering committee to bring the disciplines together, and later a risk committee and a trial committee were established. In addition, there were monthly whole of team ('Skype') tele or video-conference meetings at the beginning of the pilot, and 6-monthly face-to-face whole of team meetings that alternated between Hobart and Canberra for the entire duration of the pilot (biannual conventions or BiCONS). There were Milestone reports to ARENA every 6 months for the pilot's duration (36 months) (CONSORT, 2015a, pp.26-27).

In terms of UTAS activities, a timeline for the social research was planned in consultation with the rest of the CONSORT team; it commenced with focus groups in September of 2016 (Social Researcher, 2016, p. 4), with a plan until the completion of the project in April of 2019. However, due to delays in installation timelines, the timing of the interviews stretched out beyond what was envisaged; by up to two years in the case of some of the final pre-installation interviews. The planned dates of the social science research were impacted by a range of product, software and other external factors, and these technical delays affected the overall pilot implementation. Table 4.4 below outlines the planned implementation schedule against the actual implementation.

UTAS timeline - social science research activities		
Date	**Task**	**Implementation outcome – either as planned, or delayed**
September 2016	Focus groups (x2)	***Implementation achieved as planned*** [Actual: Sep 2016]
November 2016	Pre-installation interviews to begin as per project plan (Franklin et al., 2017, p.26).	***Implementation started as planned, then extended (delayed):*** [Actual: Oct 2016 – Mar 2018] Due to technical hold-ups and complications (such as batteries taking a long time to arrive in Australia), the pre- and post-installation interviews spanned over a much longer period than initially planned; a couple of months ended up as a year of interviews as 'rounds' of participants had installations commissioned. *Note* – the pre- and post-installation process for interviews overlapped as some households were having pre-install interviews while others were having post-install interviews.
Aug–Nov 2016 [post-installation interviews according to initial Project plan, p.35]	Post-install Interviews at approximately 2 weeks after installation or "commissioning"	***Implementation delayed:*** [Actual: April 2017 – Sept 2018] For the reasons mentioned above interviews were delayed. In addition, there was a decision over the exact timing of when an interview should take place because of the decision-making concerning when the system is considered fully commissioned. The "trigger" point of commissioning as used by social sciences was also slightly arbitrary because commissioning could be interpreted as either when the system finished installation; when the system was signed off by TasNetworks, or by the safety auditor; or finally, when the system's software was interacting with Reposit and controlled remotely from Reposit in Canberra. This last software connection marked the 'trigger' for commissioning and participants were interviewed a minimum of 2 weeks after this date.

Table 4.3. Example of UTAS timeline for implementing social science research activities

Expanding on Table 4.3 above, the post-installation interviews were delayed due to various implementation gaps. Specifically, beyond the 6-month lag on lithium battery supply when the technology was upgraded at the beginning of the pilot, there were additional technical issues. Another reason for delay was due to a software 'fix' that was required and also a 'Reposit swap out' due to one brand of inverters 'sleeping' and not being activated in the mornings by the Reposit software. This swap out was also necessary because the Reposit hardware did not meet the Australian Standards at the time, whereas the software fix was for the sleeping inverters.

A work-around software patch was rapidly developed (over a number of weeks) in order to over-ride or 'wake up' the Solax inverters. Solax is a brand of inverter with what could be termed non-compliant software for some aspects of functioning with Reposit, which was found out after the fact, after installation. The issue with the inverter 'sleeping' was due to tariff changes with which the inverters were not 'cooperating' or operating in an optimal way.

It is suggested that it is reasonable to expect research pilots to have delays, and in cases where perceived 'hold ups' are also recognised as *learning opportunities;* this aligns with supporting SNM practices. For CONSORT however, the delays were significant in terms of the implementation gap between the planned few days or a couple of weeks (for installation) to well over a year in some instances. For example, though some participants had their pre-installation interviews in 2016, BT133 was unable to be contacted for a pre-installation interview until February of 2018 (Social Researcher, 2018b) due to hold-ups. Hold ups included one installer apparently abandoning their customers (within the pilot) participant due to business management issues. In this circumstance, TasNetworks had to take over to complete this installation, as recorded in an excel spreadsheet of raw data which tracked all participants (UTAS Social Science Team, 2019). The installer in question impacted other installations too, for example, participant BT130, who had an expected install date of 25 Feb 2017, completed a post-installation interview on 10 Aug 2018 'due to install issues' with the research notes also stating: 'installer has gone awol. TN following up and will organise the install' (UTAS Social Science Team, 2019). These issues with installers were unanticipated at the start given what was thought to be a reasonable (comprehensive) tendering process. However, from what was observed during the CONSORT pilot, it can be seen that installation businesses can be small with little extra capacity to manage pressured timelines, face an uncertain work environment and high business risk (installer challenges are presented in detail in Chapter Six). Suffice to state here, the post-installation interviews were delayed to various implementation issues (a policy implementation gap) – which is relevant to the niche-regime boundary; that is, how implementation occurs in practice. Some of the problems were more technical than others, but all had organisational and social elements: they were sociotechnical implementation problems.

This section has covered governance; the team structure, workpackage responsibilities and time lines. It has also discussed details of implementation in practice.

The next section considers the management aspects of the pilot that relate to strategic niche management, so that SNM can be seen in action.

4.4 Findings relating to Strategic Niche Management within CONSORT

SNM involves people and networks to enact, and so too does network governance. In the governance discussions above, that the importance of end-users was shown. SNM involves deliberate strategies, though implicit, and are often associated with how a project or pilot is governed. SNM forms part of the theoretical grounding of this thesis, as outlined in Chapter Two; and is based on the principles of 1) aligned vision and objectives, 2) protection of learning (niche) and 3) networking and diffusion of knowledge. The PhD research involved testing SNM concepts in interviews with CONSORT pilot researchers and partners. The interviews outlined the concept of SNM and questioned the CONSORT researchers about SNM approaches and their use in relation to the pilot; and if SNM was being specifically applied within the pilot.

This section focuses on the evidence of SNM-like practices within CONSORT. It is noted that the term SNM and the key elements of SNM in theory were discussed with lead researchers and industry partners towards the end of the pilot which enabled a potentially better understanding, than in the other CONSORT researchers, who were interviewed at the commencement of the pilot.

The concepts and language of SNM was adopted in conversation by the interviewees (other CONSORT researchers), despite a lack of contact with SNM concepts previously. The SNM-like processes of the pilot were acknowledged by the pilot leader and others, sometimes unexpectedly. For example, the pilot leader of CONSORT revealed a level of frustration at another pilot partner being more successful at one of the SNM-like elements; i.e. that their team had not made the time to network as much and to promote the scientific and technical value of their work. The partner organisation had been extremely successful in promoting their own story; she hinted that a major engineering award was felt to have been received by the organisation that was less deserving because ARENA and others did not grasp the IP of ANU (Thiebaux, 2018). In this example, knowledge-diffusion and networking, as SNM-like practices, were seen as having important, differential effects, within the CONSORT teams. This situation describes the value of networking within SNM and also tensions within the team and is covered in more detail in Section 4.4.3.

The SNM elements may be described in relation to CONSORT in the following way, discussed in turn below:

- Aligned vision — from the inception of the pilot and throughout the pilot, this was managed with good communications strategies – within the pilot and with the participants.
- Protected learning niche — structure of pilot, not having to comply with regulations — an experiment that crossed over from in front of the meter to behind the meter. In front of the meter is regulated, whereas behind the meter is unregulated. The pilot is an investigation at that boundary and the transactions between both sides. Funding by ARENA provides a buffer zone from market forces. Inefficiencies of learning are tolerated because it is research, though learnings are closely documented, and progress is evidenced through the milestone reports.
- Networking and diffusion of knowledge — also known as 'knowledge sharing' by ARENA. This was through the ARENA milestone reports, published articles from team members in IEEE and other journal articles, through media conference presentations and other publications.

4.4.1 Aligned vision

Stakeholders that have shared objectives or an aligned vision are a common trait of niche projects which have been observed to 'upscale' as outlined in Chapter Two. When the concept of an aligned vision in the pilot was discussed with CONSORT research partners (9 interviewees between January 2017 and October 2018; see Table 3.3 in Chapter 3) the responses included the following:

For the Social Science Lead's perspective, the benefit of an aligned vision provided a clear scope that sharpened the overall focus —

> 'it was helpful to have a clear and practical problem…[however] the social science questions have been slightly distinct questions. [But overall], there are a shared set of objectives'
>
> (CONSORT Social Science Lead, 2018).

For the overall Research Lead perspective, an aligned vision was seen as something that emerged and evolved over time —

> 'a key point which I think we had in CONSORT [for a successful team] was an aligned vision; and being persuasive…It was a "take over the world" and that this vision, and this need to really collaborate to achieve this vision, it takes precedence over things like ego, individual interest…[and] interests of the

> organisations…we could see [a]…compelling vision of how everything was related emerge, and for me that was pretty exciting' (CONSORT Research Lead, 2018).

For TasNetworks (utility innovation) perspective, an aligned vision during the stages of the project proposal was of pivotal importance. They pointed out an intense two-week period where all teams contributed significantly to the vision—

> 'It was quite an amazing experience. There were six or seven people all working at once [on the same document, at the same time]...we worked loosely in designated sections – [but] there were comments in other sections, everyone working towards the one thing – it was effortless. It typified a constructive culture — beautifully aligned…an alignment of the planets'
>
> (TasNetworks Innovation Team Leader, 2018).

It was observed that the lack of problems on intellectual property were also noteworthy, and that having an aligned vision or shared objectives contributed to this —

> 'Battles around IP haven't been a thing or an issue – but it has been in other projects. The environment around IP has been great, internally there's been no friction'
>
> (TasNetworks Innovation Team Leader, 2018).

Having an aligned vision seemed to encourage extra effort by all parties, in terms of time, of financial investment and more resources. However, from the perspective of TasNetworks the idea of an aligned vision was thought to be more about momentum and commitment rather than only meeting business objectives —

> 'From TasNetworks' point of view – it was more momentum than it being strategically important [because it was not] time critical. It has gathered its' own momentum, and it's a great story for customers and the PR is strategic'
>
> (TasNetworks Innovation Team Leader, 2018).

Interview data from the CONSORT research partners thus demonstrates that there was an aligned vision and shared objectives. It is suggested below that the influences of collaboration and leadership are linked to an aligned vision. However, before discussing aspects of collaboration and leadership as revealed by CONSORT partners, an example is given of an aligned vision at play with the researchers, and participative-action research is described in an ethnographic sense.

As a researcher, it is recognised that being neutral social science observers was not fully possible with the kind of fieldwork the CONSORT social science team were undertaking. In many instances during household interviews the author as part of the CONSORT social science team, would offer to record details of technical problems that the participants were having, so that these could be passed on for an expedited resolution with a pilot partner. Many of the participants appeared to be grateful for this assistance rather than proactively following up themselves; some participants had difficulties they did not know how to resolve, and in fact did not know who was responsible — they may have not known whether they should be contacting the network utility, the ICT company Reposit, or the inverter manufacturer. The participants had found particular difficulty if their installer was not able to help, and the complexities were compounded with changes to metering and tariffs which occurred coincidentally during the trial and created confusion and software issues.

An example is elaborated upon below as a key instance where the author and a co-researcher undertook a face-to-face interview with a householder at their home that demonstrated learning through ethnographic data-gathering for the author. On the morning of the 9th November 2017, the PhD researcher and co-researcher arrived for an interview with two participants that would be expected to take between 45 minutes and an hour and 15 minutes, as is the norm. The interview in this case was expected to take a little longer due to a photographer arriving to take photos of the participants with the researchers, and the technology in place, for a local newspaper and university newsletter. What transpired was more than expected. The interview began in an unconventional way, with a passing introduction to a pair of interested, but silent, listeners who were sitting in an adjacent room, before settling at the kitchen table to start the interview. Halfway through the semi-structured interview, the photographer and his dog arrived (for a UTAS website/story on the CONSORT pilot). This led to the interview being paused, and the parties moved outside to take photos. At this stage a mild amount of background activity and commotion started, involving the participant's dog, the photographer's dog, the arrival (at that point) of a water truck and a local friend who had arrived to clear the borehole in the participants' back yard. The owner of the water truck, before turning on this extremely noisy equipment, had arrived with a toddler on his hip, and explained that his work was necessary and urgent, so these activities all occurred simultaneously.

The photographer left after half an hour and was in a rush to get the return ferry. While having photos taken, the participants explained their internet connection had been an issue and because of this they had not been able to initiate the Reposit software.

The situation with these participants was that the distance between the Reposit software (battery) and the modem was too far, and also the battery could not be commissioned from the point of view of energy trading on their behalf (i.e. operating), until this connection could be established. The participants had already spent months speaking with the installer, Reposit, the network utility and their telecommunications service provider, and were frustrated as a result. As an additional frustration, they had found that they could possibly initialise the internet connection required to Reposit, if their current mobile phone was working (it was not). One of the first questions asked by the householders of the researchers when they entered the house was if it was possible to borrow the PhD researcher's mobile to see if a connection could be established.

The interesting aspect of this, is that for the researchers to remain objectively observing, providing assistance would not have been a valid option. However, there was an active interest from the researchers in the technology reaching a point where participant responses to the NAC and the use of the battery could be observed, and given that meeting the objectives of the pilot, the social researchers found that they were required to become active and participatory (rather than only observing and recording, which was the original intention). This action-research approach was extended officially to altering the interview schedules to reflect the requirement that gathering information on issues to report back to the technical teams was a valuable option to include for participants, so that successful deployment could be achieved in a timely manner.

In the case described above, the author did attempt to provide a portable hotspot (roaming internet connection) to initialise Reposit; while at the same time the participants were on the phone with Reposit in Canberra to see if they could initialise it at that end. The strength of the internet signal was weak and so the PhD researcher attempted to gain elevation by standing on top of the water truck. It is noted that this may appear non-objective (unscientific) yet it is ethnographically embedded to the rolling out of one of the battery systems and seeing how (and if) it worked, so in that sense, describing this ethnographically, provides elements of the reality that are invisible otherwise. In the end, further advice was sought, and the PhD researcher contacted a source in the telco industry in the state whom the participants spoke to— the source re-iterated what the participants had already been advised (to get a device that amplifies the Wi-Fi signal from the fixed line inside the home, sometimes known as a repeater).

To the PhD researcher's best knowledge, the participants resolved the connection issue and the software through Reposit was initialised shortly after they got the said device.

All in all, the actual implementation was a complex procedure, involving many parties, different organisations (the telco, Reposit being communicated with at that time to try to understand what the issue was) as well as assistance from the researchers on the day which may have sped the process up a little, rather than to merely observe, record and not assist, which would not be beneficial for the trial. In this sense, the researchers, as active participants within the research pilot are therefore not neutral which is justified given the *aligned vision* that the researchers have with the goals of the pilot overall.

As mentioned above, a final thread that supports SNM, that was observed within CONSORT, but is not emphasised within SNM scholarship is *collaboration and leadership*. It is argued that this theme supports aligned objectives and shared vision within SNM practices, and so the next sub-section is devoted to this, to contribute to existing scholarship an element of SNM that is not a traditional focus of SNM.

4.4.1.1 Collaboration and leadership

The Research Lead emphasised in her interview that the project plan and proposal was written by collaboratively —

> 'The way we wrote the project proposal — at the main stage of the application — I had it structured in parts – and everybody had a part to write. All [teams] did it in Google-docs. I had a view of how everything was related, and you could see people's thinking evolve as we went. I haven't seen it work as well in previous applications'

(CONSORT Research Lead, 2018).

Normally a pilot of this size would have an institutional research-lead that may be expected to be more prescriptive—

> 'That was not the case here at all — every organisation took a substantial part and effort in writing this proposal…and you also understand the constraints of the other partners...that TasNetworks said they were going to manage the installs as 'non-negotiable' I only started to see how that was the best thing [as the plan evolved]. TasNetworks and Reposit had to agree on remuneration – how that was progressing – there were pairs of conversations – but you could see how all that was evolving'

(CONSORT Research Lead, 2018).

The Project Lead explained that she went to effort to ensure a particularly collaborative style of leadership —

> 'I really tried to do throughout the project…maybe too much…I decided early on [what] it wasn't going to be like...everyone would be significantly involved, making decisions and leading…I see CONSORT as everybody's leading'

(CONSORT Research Lead, 2018).

Regarding management learnings on the pilot and what made the pilot successful, two things were made clear; first was the amount of joint effort, responsibility and credit, and second was the effort and facilitation by the research leader —

> 'Everybody would say that...all organisations [in CONSORT] can absolutely claim they have led the project to where it is now…One thing that played in our favour was that it was the first time I was applying for ARENA funding. I had a good chat with my Dean leading up to this – saying – look, I have fantastic team, fantastic people, they are going to go, if I, if basically, the college doesn't try to retain them; and she encouraged very strongly…and I think she really motivated me to make this a success…She was a new Dean…I absolutely couldn't screw up this proposal, it had to get a lot of my attention, and a lot of my priority. This is why we were early, and we were organised, I didn't know what to expect, I hadn't done it before, it required substantial organisation. It ended up being a proposal they couldn't reject'

(CONSORT Research Lead, 2018).

No project is without challenges and difficulties, but even as late as October of 2018 (nearing the end of the pilot), in interview the Innovation Team Leader at TasNetworks described the 'collaborative' leadership in CONSORT, the 'constructive culture' and 'business leadership' (TasNetworks Innovation Team Leader, 2018). It can certainly be argued that collaborative culture is important, not just for the CONSORT team, but for the participants who are also learning.

So far, this findings section has discussed SNM relating to evidence of an aligned vison, collaboration and leadership from the top-down, that is, from the CONSORT leadership team. Despite the findings in this section which fit positively with SNM-like practices, as a research project there were of course instances of conflicting ideas and partial implementation failures, and particularly where they intersected with the participants. These challenges were significant at times and could be usefully be framed now as learning opportunities. For example, a year after installations commenced it was observed that there still seemed to be confusion among participants and enthusiasm for more information and discussion — as a consequence, TasNetworks implemented a private online participant portal. Engineers and others could answer their technical questions online and others could see. This was designed to foster an open and collaborative culture for the participants. The TasNetworks Customer Engagement Advisor saw this as a positive step —

> '[The] online chat—helps with trust — removes a barrier and [encourages] learning from each other – even bad experiences, because it provides an open and transparent approach.'

(TasNetworks Customer Engagement Advisor, 2017)

Moreover, it is argued here that to align truly with SNM-like practices that it is not just the project team and stakeholders that should have an aligned vision: but it includes the 'forgotten' implementers themselves, the installers as well as participants — and despite the best of intentions. One participant described the implementation as 'piecemeal' indicating a lack of collaboration; and responded in the following way on his experience of the system installation —

> 'Ongoing confusion. With all aspects, to be honest. Critically, that included the scale, location and design of the battery and other equipment, which was eventually only done on an evolving basis when it was supposed to be installed. So it ended up being three times as big and having to be relocated to a different location altogether. And clearly, also, nobody knew what it was going to be – no thought had been given by anybody involved into what was required.'
>
> (BT128, 2018)

This lived experience of a participant shows an example of how highly critical some participants were of the coordination of the pilot and points to a lack of communication and collaboration between the installers and the rest of the CONSORT team. The importance of the installers for implementation is a crucial issue, covered later — as the focus of Chapter Six.

In summary, having a project team and stakeholders with an aligned vision is a critical *starting point* of SNM and successful implementation. However — more attention on the *end-users* of implementation (e.g. householders) and the *implementers* (installers in this case) would have been highly impactful. As part of a social science team, this researcher felt that by the end of the project that the installers could have been brought in more collaboratively to the project overall; although an aligned vision of what CONSORT was attempting to achieve was relatively unified.

The following section, as part of SNM, the 'protected learning niche' is described as it was observed in the CONSORT pilot.

4.4.2 Protected learning niche

The pivotal aspect of CONSORT that confirms a 'protected learning niche' was the funding. The funding contributed, from ARENA and (in-kind and cash) from the research partners, meant the pilot was protected from market forces during the learning or R&D stage. 'CONSORT is a $8M project, requesting under $2.9M from ARENA…[whereby] the 5 partners are contributing nearly 2/3 of the project funds' (Thiebaux et al., 2015, p.17).

CONSORT as an experiment, requiring a protected niche for survival and development, was outlined by The Project Lead—

> 'Yes… it's protected in this sense…I don't see that this would have happened [otherwise, because] …we didn't have all these barriers of making money, [or] complying with some very stringent regulation. On the other hand we did have…a high expectation with respect to consumer engagement…we couldn't screw up — the consumers had to be better off...and this is why I think a lot of accent was put on the consumer angle'

(CONSORT Research Lead, 2018).

The importance of consumer engagement was why TasNetworks suggested the UTAS social science team to be involved –

> 'TasNetworks are really competent on the consumer engagement angle. But we [still] weren't completely protected on the consumer engagement angle…[and]…it definitely could not be a failure from the consumer point of view' (CONSORT Research Lead, 2018).

The ANU perspective also brought together the understanding of the necessity of the protected niche, and deeper second-order learning as a path to deployment to help solve large issues –

> 'A new company in this space would not survive...It would have been difficult to create the technology that we created...if you are going to only fund things that are going to have 6 months to a year commercial outcome, then you will not solve the big problems of the electricity grid in my view'

(CONSORT Research Lead, 2018).

The critical importance of ARENA as a protected-niche provider for this sort of development was echoed by TasNetworks —

> '[CONSORT] wouldn't exist without ARENA support'

(TasNetworks Innovation Team Leader, 2018).

Other elements of an aligned vision were also recognised, in-kind-contributions are important, and that time is a precious resource that was freely given due to an aligned vision and shared objectives on the pilot —

> 'TasNetworks cash and in-kind was huge…people were, and are, super onboard with the project and this is why we're succeeding. And the reason they're super on board is they can see the value with respect to their own objective, and they believe in the vision, I think'

(CONSORT Research Lead, 2018).

The next section on the SNM analysis is networking and diffusion of knowledge.

4.4.3 Networking and diffusion of knowledge

Under Commonwealth law, the ARENA Act of 2011 is directed to share knowledge on renewable energy technologies, and to promote this activity to project agents. The rationale for knowledge sharing is that the projects are publicly funded so that IP developed should be used for the public good; this is seen as a return on investment, and further, knowledge sharing 'helps to build a stronger, more resilient energy system with increasing levels of renewable energy' (CONSORT, 2015b, p.1, Knowledge Sharing Plan).

Some of the knowledge-sharing objectives in the CONSORT Knowledge Sharing Plan were specifically prosumer-focused, and relate directly to social science research, namely:

> '(e) improved understanding of householder responses to the PV-battery technology installed…in order to improve understanding and assist with design of household systems, commercialisation readiness and improved design parameters;
> (f) improved understanding of needs of customer and customer engagement processes in technology trials; [and]
> (h) increased public awareness and understanding' (CONSORT, 2015b, p.2).

ARENA directs that 'key knowledge sharing audiences' include ARENA, the AER, the Commonwealth, the electricity sector and peak industry bodies, community groups and researchers. There was a range of categories of learning outlined in the CONSORT Knowledge Sharing Plan, including technical (engineering, computing, economic), and societal and regulatory categories. Societal knowledge-sharing is the 'analysis of householder responses to technology' and regulatory knowledge sharing targets 'policies that would increase the adoption of PV-battery systems by residential customers and accelerate deployment in Australia' (CONSORT, 2015b, p.6).

> 'CONSORT will create and capture knowledge that includes societal knowledge and regulatory knowledge'
>
> (CONSORT, 2015c, p. 19).

The idea of 'Knowledge Dissemination' includes technical and financial knowledge, and extends to the expectation that knowledge transfer would also include societal and regulatory knowledge —

> 'Societal knowledge: …this will be widely disseminated to the academic community via publications in conferences and journals. Higher level aspects will also be communicated to the renewable energy industry' and other avenues such as public talks and media'
>
> (CONSORT, 2015c, pp.21-22)

Regarding regulatory knowledge —

> 'Regulatory knowledge…will be communicated to influential stakeholders…
> Finally, a key aspect of CONSORT will be to educate Bruny Island consumers and installers about the technology deployed and understand how they respond to the technology'

(CONSORT, 2015c, pp.21-22)

For the UTAS perspective, the challenges were due to the different expectations of what constitutes important knowledge dissemination, given both academic and commercial interests within the pilot —

> 'There have been some tensions in project team and organisations – Reposit and TasNetworks have staff purely on communications and marketing – this makes it more challenging [for academics]. [Also] the messages we want to put out are different. Academics are not as interested in growing the market…[and] we think about knowledge dissemination in different ways. [CONSORT fieldwork with] longitudinal interviews has only just finished- and to distil out key findings takes time, and ARENA…are not very interested in the academic publications that would come out of the project'

(CONSORT Social Science Lead, 2018).

For the Research Lead's perspective, a point of contention was the perceived importance of networking and knowledge dissemination but lack of investment of this externally —

> 'I think it's crucial but…we could have done more. The world is moving a bit; not taking into account as much what we have done…some individuals were very good at networking and talking about their view of a problem; and they do have a lot of influence. If my group had [more] time to actually do this, then maybe the future of CONSORT would have been in a better position'

(CONSORT Research Lead, 2018).

The Research Lead expressed a sense of frustration at the apparent lack of knowledge-diffusion or effective communication to outsiders, including ARENA —

> 'Even ARENA, I think until recently…they struggled to see the difference between various trials. We didn't win the [engineering] Australian national award, Reposit won it…I'm guessing it's the way we presented it…so even though I thought it was compelling it wasn't compelling for the jury. [Because] a lot of people use the same language, and the [ANU] NAC versus [Reposit] Fleet, there is a big difference – but I'm not sure how the rest of the world understands this'

(CONSORT Research Lead, 2018).

4.4.4. Knowledge Sharing, contingent implementation success, and learnings

The CONSORT pilot won three awards during 2018, two were for engineering, and one was for community engagement. Specifically, they were: the Clean Energy Council Business Community Engagement Award (national award) (TasNetworks) (CEC, 2018); the Tasmanian Engineering Excellence Award (ANU, 2018); and the Energy Project of the Year, The Electrical Energy Society of Australia (CONSORT, 2018b). The awards were taken by people, both inside and outside the team, as a measure of success of this particular pilot**.** The depiction of this success of the trial in the media is at odds some of the realities of the project, in particular, that there were delays and problems that needed to be resolved, including for the participants' as end-users. So, despite the appearance of prolific networking and diffusion of knowledge and recognition in the pilot, like any project, it was not a full success 'on the inside'. Partly this was due to learning, but also delays and patches and unexpected events and issues, but also included varying objectives and their commercial vs academic objectives for success; one issue was the NAC not being understood and that it was hinted this may have meant that Reposit won the award rather than CONSORT more widely, despite the more advanced algorithms and problem-solving at a detailed (battery) level.

Dissemination included journal papers, media and various presentations and workshops. A few journal articles were published over the course of the pilot and others are still being developed. Papers written to date were for *Institute of Electrical and Electronics Engineers* (IEEE) journal articles, (Mhanna, Chapman et al 2018), and from the social sciences, in the journal *Energy Research & Social Science* (ERSS) (Lovell, et al 2017). Media included *The Conversation* (Ransan-Cooper, Chapman, Scott, & Hann, 2018). *The Conversation* article was included as part of an ARENA milestone due to the 'educated layperson' style of language and wide reach for communications. Additionally, a workshop and presentation of final results of CONSORT was held for key industry, government and academic stakeholders at the University of Sydney in May of 2019. Further knowledge-sharing is evidenced by a whole-of-team submission that was prepared for a federal-level Consultation Paper; a joint Energy Networks Australia and Australian Energy Market Operator project — *ENA-AEMO Open Energy Networks* in Aug 2018 (AEMO&ENA, 2018), and numerous attendances and presentations at various conferences and meetings. Knowledge sharing was about dissemination, and also about the learnings. Indeed, learnings are a critical reason for conducting the pilot.

At a high level, from a governance point of view and lessons learnt, the September 2108, Milestone Report 5 'Lessons Learnt' included a key lesson on 'Good governance for DER deployment'

> 'The key learning was the understanding of the importance of 'systematic, well-planned consumer (and installer and organisation) support is required to ensure low-risk governance (and efficient deployment of) distributed energy resources (DER). Governance models and management systems

involved in two-way, controlled, distributed energy provision will need to ensure that they identify key organisation(s) to be responsible for providing necessary support to householders, installers and other organisations involved (CONSORT, 2018a, p.3).

Outlined were four areas for consideration during future projects or as part of future regulation and policy in rolling out DER more widely in Australia, in summary, they were:

1. Neutral technical oversight
2. Technical support and accreditation for installers
3. Reliable and detailed, but easy to understand information
4. Consumer protection checks

(CONSORT, 2018a, p.5).

Further, the CONSORT team submission to the Consultation Paper mentioned above for the ENA-AEMO Open Energy Networks Project shared learnings from the CONSORT overall report. The final CONSORT report however, titled 'Lessons Learnt During Trial Deployment', was not released until April 2019. This report essentially pointed to four key elements in relation to learnings on governance of the technology. These were factors of *regulatory access* (open access technology within a 'variety of platforms'); *cost*; *coordination* 'within management and market systems'; and *simplicity* ('minimal data collection effort') (Jones et al, 2019).

The CONSORT Social Science final report highlighted that effective governance is unlikely to occur if householder participation is taken for granted; if mainstream householders are expected to be similar to early adopters; and if householders are expected to respond to the technology homogenously (Watson et al, 2019, p. 8). Industry and government are effectively warned about the difficulties in governance ahead if these findings are not considered. Education and information, integration and coordination are again themes in relation to governance, it was found within CONSORT that:

'there are some organisational gaps in new household-DER-network configurations, such that key tasks are not necessarily happening, e.g. education about the installed (combined) DER technologies, ongoing troubleshooting, tariff changeovers' (Watson et al., 2019, p. 41).

Overall, it can now be seen that SNM-like practices were deployed within CONSORT. Despite this, there was no prior awareness of SNM as a policy tool by most CONSORT researchers, and there w no officially documented SNM-policy strategy, either by CONSORT or ARENA. Even so, the pilot actions were strategic and describe elements of SNM-like practices. The intense collaboration at the EOI stage by CONSORT researchers demonstrated the rapid and organic evolution of an *aligned vision*;

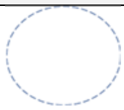
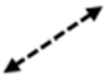
the networking and subsequent tensions concerning communications and the engineering award evidenced the differential ability of the pilot's teams to *network*; the inclusive network-governance style of leadership by the ANU Lead, as well as the ARENA funding are argued to demonstrate the three key features of a *protected niche* quite clearly. These findings were evidenced by documents and the interviews and is argued to substantiate the claim that CONSORT exhibited SNM-like qualities within its' activities.

In summary of the analysis of SNM and its application to CONSORT, answers can be given to the three SNM criteria or questions: Was there a protected niche? Were there aligned objectives and was this alignment maintained for the most part? Was networking and knowledge diffusion fostered? CONSORT was indeed provided with a protected niche (mostly through ARENA and through TasNetworks, but also in-kind through researchers' efforts); CONSORT did maintain aligned objectives, not just on paper, but through researchers' and pilot partners' efforts, including out in the field. This is not saying that perfect alignment of objectives is ever truly possible — but to a significant extent it was proven. Finally, knowledge-sharing was demonstrably undertaken, and significantly this was propelled by ARENA objectives.

4.5 Discussion and Conclusions

This chapter links the case study — as a managed niche-level project — to SNM as part of the theoretical enquiry of this thesis. SNM is a concept about the upscaling of niches. SNM was not adopted by CONSORT, but nevertheless it was found that there were SNM practices used by the pilot team. A two-step research approach was undertaken. In the first analysis, the official, explicit, documented evidence of governance, management and policy implementation was examined. Then, the implicit (undocumented) evidence of SNM was identified through interviews with the pilot team and analysis of key project documents. At the beginning of this chapter the value of a project ethnographic techniques were explained as a mechanism for detailed, (unofficial) embedded information gathering that can add to learning, and this was used in particular to demonstrate the (imperfectly) aligned vision that the CONSORT researchers/partners had as part of the pilot, and the active, participatory research style in this chapter.

In fact, the social researchers acted to influence the outcome of the pilot, partly by facilitating between the participants and the technical teams to help expedite solutions (i.e. implementation). These interactions, which from a strict social science perspective might be seen as interference, were a form of important action-research learning for the social science team and the other CONSORT teams more widely. The purpose of the pilot was to demonstrate the implementability of a new technology that is occurring already in a niche sense in Australia, and has potential to become mainstream, as driven by end-users or energy consumers. To clarify however: this thesis argues that the new technology is not related to the type of battery or the NAC, but of successful *coordination*. That is, for smart-grids — as internet-enabled households with distributed 'smart' storage with the ability to be both used and traded at the household-scale. Current battery technologies and coordinating battery management software may supersede what is observed in the current pilot. Regardless of this pilot, or others, it is consumers that are significantly driving change given the configuration of consumer-preferences and values, underpinned by technology, economics and policy. Thus, the end-user implementation is central; this is a small-scale influence (at the level of individual households), and so therefore from a project perspective SNM was useful, as it is matched at the same scale. As mentioned, from a top-down policy perspective, ARENA strongly

Key: CONSORT pilot— Shared learning and knowledge diffusion	
	Dotted circles represent the pilot partners as CONSORT teams, comprising industry and academia.
	Black dashed arrows represent intra-project, two-way diffusion of learning and knowledge exchange between the pilot partners and pilot.
	Blue dotted arrows represent inter-project, two-way diffusion of learning and knowledge exchange and may extend beyond ARENA, to external stakeholders, government and wider community.
	Blue dots represent CONSORT PhD resources (4FTE). Each blue dot has overlap, contribution and learning with four aspects: the home institution and team; overlapping within the institution's CONSORT remit; fitting within the institution/team's core discipline; and outside theory and knowledge being developed and brought in; as well as additional learning from other pilot partners. The flows between the four areas can add to learning and knowledge sharing overall. Note: this diagram does not consider methods of sharing (e.g. through the pilot committees).

encourages SNM-like behaviour through knowledge-sharing, and sponsors protected niches. This SNM-like behaviour is implicit, and the knowledge-sharing and diffusion of knowledge are of course key elements within SNM. The internal and external knowledge sharing and diffusion of knowledge within CONSORT is be depicted below in Figure 4.4.

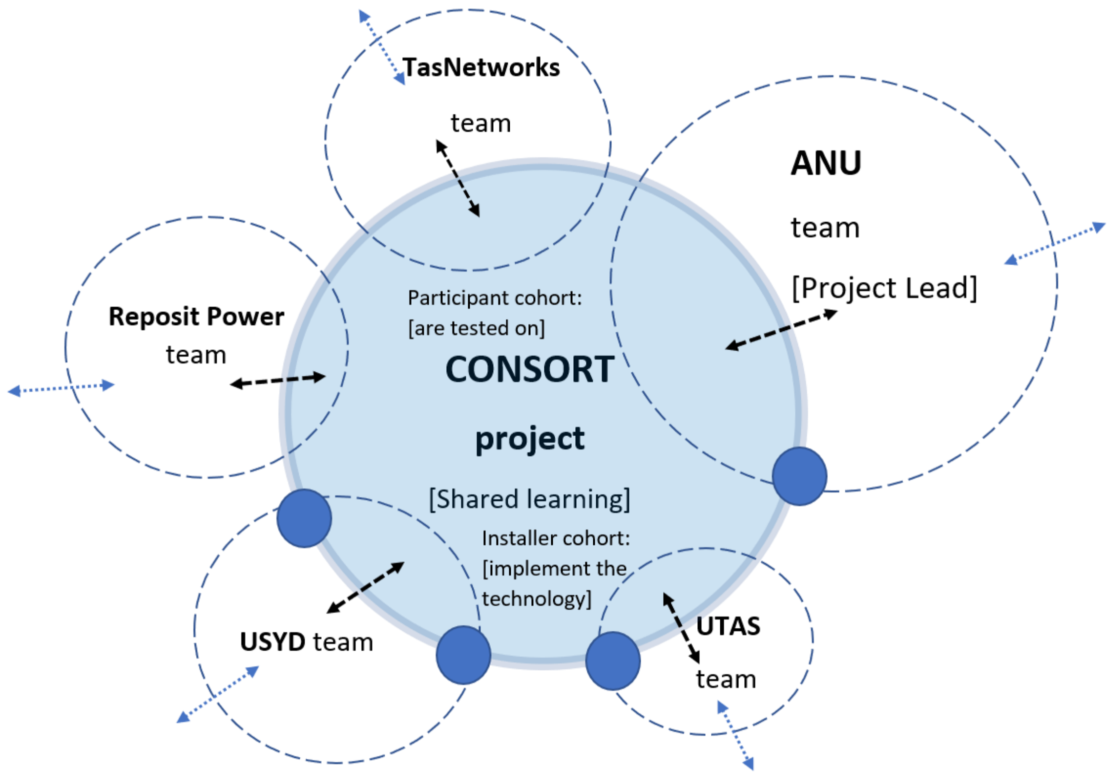


Figure 4.4. CONSORT pilot— A proposed model for shared SNM learning and knowledge diffusion

In summary, this chapter provides an insider's view to an ARENA project and attempted to direct particular attention to the end-users of technology as customers are known to be driving system change with consumer preferences. The CONSORT pilot was positioned at a technology readiness level of 3, which lifted to demonstration phase TRL6-7 due to the pilot's implementation. All interviewees and pilot leader agreed that the pilot would not have proceeded without funding, even though only a third of that came from ARENA. The social science value was deliberately emphasised in this chapter and was done so because it was becoming apparent that end-users and a focus on consumers is 'closing the loop' as far as demonstrating technical pilots are concerned. A focus on consumers helped in closing the implementation gap in this pilot.

Within the CONSORT pilot, collaborative leadership was a significant factor in fostering a positive, proactive culture, sense of commitment and ownership throughout the pilot teams, but this did not always flow on to implementation, for example, as observed with installers.

CONSORT demonstrated a few key aspects of SNM: namely, CONSORT was very strong in the alignment of vision and stakeholder objectives from the outset; the pilot was protected from outside market forces so that it had a chance to grow and develop. Networking and diffusion of knowledge was highly successful, although this was the point of team divergence, especially regarding the effectiveness knowledge dissemination. This divergence is attributable to the different overall objectives of the organisations and the values of different types of knowledge within them. The September 2018 Milestone report on knowledge sharing and lessons learnt included a significant learning associated with governance. And, this was with outwardly focused on installers, information flows with prosumers, regulatory policy on accreditation and neutral technical oversight with rollouts especially at this early phase.

Collaborative leadership and embedding more input from partner organisations in the project development phase — rather than the one-lead-institution model — may be a successful model for increasing stakeholder alignment from the early stages, as demonstrated in the CONSORT example. A next step towards a sustainable transition is how to institutionalise other aspects SNM, such as creating virtual technical and policy hubs for similar projects under the ARENA banner. Finally, in terms of policy learnings, it is suggested that SNM learnings from the pilot may be considered useful in terms of institutionalising some elements of SNM practice. It is noted that CONSORT team members were not 'actively embracing SNM' as a policy tool or engaging with the parlance of SNM concepts prior to interview, but nevertheless, SNM-type processes existed within CONSORT.

It is argued that some SNM-practices may be effective and might be possible to institutionalise, that it may be possible to formalise SNM-like activities within governance structures. Arguably, this is already happening to some extent within ARENA. However, this does not reduce the significant practical difficulty in attempting to implement SNM as a suite of policies by government. Criticisms of SNM are well founded; and though SNM does seem, theoretically, to hold promise for governments endeavouring to enhance niche-level, socio-technical programs (Mourik & Raven, 2006), governments are acknowledged to be cumbersome bureaucracies with multiple agencies, sometimes conflicting objectives, and burdened with the perennial issue of politics. Additionally, the role of non-government actors (including entrepreneurs) is important in niche management and may be underplayed within the understanding of SNM. In this context, it might be sensible for governments that are grappling with technology and innovation policy to consider a 'greater allowance…for non-governmental actors taking a lead role with regard to niche management…[which would] consider a range of different organisation[s]' (2007, p.42). This is an important point — the understanding and incorporation of non-*governmental* actors within SNM — hinting at a network governance approach, an approach covered in detail within the theoretical basis of this thesis in Chapter Two.

It is argued here that policy implementation effectiveness may be improved with SNM-type practices; as SNM acts to upscale and successful implementation has the identical effect. Thus, SNM-like practices may improve the likelihood of implementation success, and successful implementation and deployment may be equated with a niche break-through to the regime level if it occurs in large numbers (though it is at a small-scale). That is, it is argued here that small-scale residential storage uptake appears more likely to add capacity to an energy system more quickly than large-scale storage projects due to the large capital costs and regulatory barriers known to be associated with large-scale projects. SNM-like activities are deliberate strategies and actions that fall under the governance of niche projects. It is argued that, conceptually, SNM and network governance are mutually amplifying in effect. In addition, it argues that agencies or projects that appear to support SNM-like activities (such as networking and knowledge diffusion) are enhanced within network governance structures, because network governance facilitates knowledge-transfer similarly to SNM.

It is noted here that the author believes that the useful application of SNM-like practices has the potential to grow into the future given the trajectory of technology in society towards IoT-integration. The growing presence of IoT is argued to facilitate knowledge-sharing platforms and innovation hubs in a way not envisaged in the past, and certainly not when SNM was first developed as a concept.

A contextual lens and outline for Chapter 5

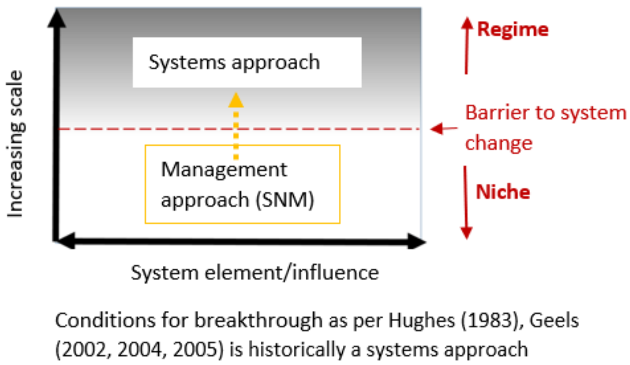
This outline introduces the empirical paper 'The precursors of acceptance for a prosumer-led transition to a future smart grid' that is in the place of Chapter Five, which is submitted and is currently and under review with the journal '*Technology Analysis & Strategic Management'* and co-authored with Dr Philippa Watson. Note that there is some repetition of earlier content of the thesis, in terms of background on Consort and theory, because it is a journal paper [in a journal paper format].

The key relevance of this paper is the empirical evidence and theory provided that relate to a theoretical prediction in how future network utilities and governments may potentially 'manage' an orderly transition through a process, and heuristic, of technology acceptance. The original contribution is of the exploration of the gap between network objectives and consumer intentions in relation to implementing innovative technologies, and the resultant heuristic that suggests an equilibrium exists between agency and trust.

The empirical material this chapter draws from is interviews with CONSORT participants, the installers, the TasNetworks engineer and customer engagement advisor, a manager at Reposit Power, a project manager of another ARENA project, the CEO of the AER, and the president of the Smart Energy Council.

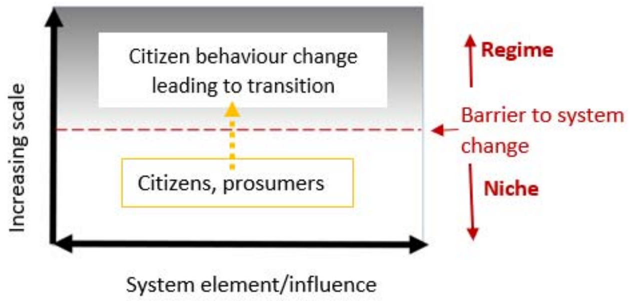
Chapter Two sets down the overarching framework for the thesis, but greater theoretical detail is explored in this paper in relation to 'precursor-to-technology-acceptance' factors that may enhance a prosumer-led transition. This paper develops more nuanced definitions and relationships between the themes of engagement, agency, trust, and acceptance that may encourage a prosumer-led transition.

The schematic below represents aspects that relate to Chapter Five. Similarly, to the previous empirical chapter, some areas overlap, in terms of 'niche conditions that contribute to innovation breakthrough'. This paper takes a network and management perspective (though not specifically SNM) and so it is argued that a management approach as seen in the illustration below (managing prosumer information and expectations) may support scaling up of innovative technologies.



Niche conditions that contribute to innovation for breakthrough, Schematic A

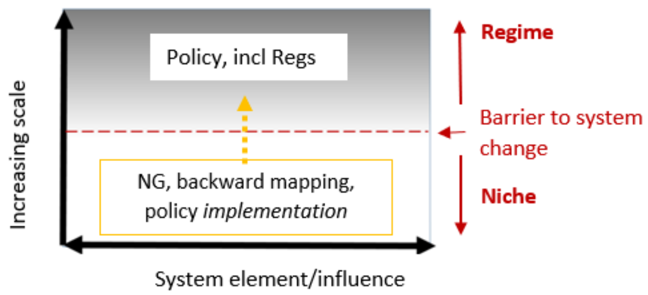
Citizens and 'proto-prosumers' are central to this paper., in the sense that 'proto' means that the mainstream are not yet prosumers. Consumers driving demand and transition is central because it is argued that it is the relationship between the network objectives and the consumer intensions that define what type of transition, if any will occur. The illustration below, the 'citizen behaviour change leading to transition' is highlighted as a theme for this paper; whereby behaviour change is equated with consumer preferences (to purchase an internet-enabled battery, or not), and with acceptance and adoption of a new technology.



Conditions for breakthrough as per CSIRO (2014), AEMO (2016) are driven by a high level of prosumer participation

Niche conditions that contribute to innovation for breakthrough, Schematic C

Finally, the schematic below indicates policy development and implementation that relates to the consumer. This paper suggests policy learning (the process-heuristic) that may at a future time be applicable for network utilities in terms of managing prosumers.



Conditions for breakthrough as per Elmore (1979), Fiorino (1997), Voss et al (2009). Where policy development = implementation

Niche conditions that contribute to innovation for breakthrough, Schematic B

Therefore, Chapter Five empirically examines the role of management, policy and citizens in driving change, as key elements that may accelerate a socio-technical systems transition, and drawing on new primary empirical data from the CONSORT pilot.

Chapter Five

The precursors of acceptance for a prosumer-led transition to a future smart grid

Abstract

A sustainable electricity transition towards greater distributed storage is marked by a changing relationship between consumers and utilities. Evidence of this changing relationship is observed through a PhD investigation within a three-year, AU$8M Australian smart grid pilot, known as CONSORT *(CONsumer energy systems providing cost effective grid suppORT).*

This paper investigates the under-explored gap between the electricity network objectives and consumer intentions in relation to implementing new technologies. This gap; as measured by consumer acceptance, presents a risk to the implementation of new sustainable technologies, and hence, a risk to an orderly electricity sector transition. This paper proposes a theoretical heuristic to assist understanding technology acceptance, from the electricity network perspective.

We outline three major findings. First, that prosumers require significantly higher levels of *customised* education and engagement than is currently being offered to deploy smart grids successfully. Second, we found that prosumers do not always desire *increased agency*, but may wish to instead 'trade' agency, which may occur where levels of trust are sufficient, and this is a method to reduce complexity for the consumer. Third, this paper suggests that trust, as a method for reducing complexity, may be even more important than education for a future IoT energy system.

5.1 Introduction

This paper is the result of a PhD investigation that examined technology acceptance in a socio-technical smart grid pilot undertaken on Bruny Island, Tasmania. The pilot project tested the implementation of internet-connected batteries and solar panels, as a distributed renewable energy storage solution.

The CONSORT pilot was conducted in response to changes occurring in the consumption and production relationship between utilities and householders, underpinned by residential distributed storage. Electricity in centralised grids, was for 150 years a one-way provision; and treated as a public good; and under the responsibility of a utility (Hughes, 1983). However, with advances in 'smart' batteries a new era of two-way trade of electricity and economics has emerged, and with it, increased consumer agency. Electricity that is stored in privately-owned residential batteries is now regarded as a private good; up for negotiation. This transitioning relationship between privately owned (behind-the-meter) storage and networks is recognised by governments as transformative (AEMC, 2017a, p.2; ARENA, 2018c; CSIRO, 2014).

The CONSORT pilot (2016 – 2019) was a multi-disciplinary partnership of industry and academia comprising three universities: (Australia National University (ANU), University of Sydney (USyd), and University of Tasmania (UTas)); a distribution network incumbent (TasNetworks); and ICT software new entrant (Reposit Power). The pilot trialled the technical; economic; and social feasibility (led by ANU; USyd; and UTas respectively) of operating a fleet of household batteries as a Virtual Power Plant (VPP). Essentially, a VVP operates by software managed at a network-level that enables the orchestration of householder battery systems for grid support. This VPP augments the island's constrained undersea cable at times of peak electricity demand. Hence, battery support becomes a procurable service by the network providers who pay the battery owners (prosumers) for off-setting electricity consumption during peak demand.

The University of Tasmania social research for the CONSORT pilot explored householder (prosumer) responses to the technology. A critical element, and the focus of this paper as a PhD investigation, was whether (and how) householders accepted the technology and the new trading relationship with the network. Indeed, ultimately consumer *acceptance* defines whether a new technology will be implemented (Burchell, Rettie, & Roberts, 2016; Chilvers, Pallett, & Hargreaves, 2018; Davis, 1985; Ellabban & Abu-Rub, 2016; Hess, 2014; Huijts, Molin, & Steg, 2012; ISGAN, 2017; Joshi, 1991; Marangunić & Granić, 2015; Noll, 1992; Toft, Schuitema, & Thøgersen, 2014).

To examine pathways to acceptance of technology this paper asks: ***What are the conditions that lead to consumer acceptance of a new technology (smart batteries)?*** Examining acceptance from a network-level perspective, a second question is; ***How might the enabling conditions be related in a way that may assist utilities and prosumers to accelerate a transition?***

Findings may be useful to understanding how industry participants may adapt their consumer engagement strategies into the future to encourage acceptance and thus manage the transition to a hybridised electricity system in a stable manner.

The remainder of the paper is structured as follows; Section 5.2 investigates the scholarship that lead to consumer acceptance of new technologies; Section 5.3 outlines the methods and describes the approach of analysis; Section 5.4 presents thematic findings from the CONSORT pilot according the framework of analysis; a Discussion in Section 5.5, followed by Conclusions in Section 5.6.

5.2 Literature review

The understanding that residential energy consumers are pivotal to implementing a future electricity grid is well recognised (AEMO&ENA, 2018; CSIRO, 2014; Finkel et al., 2017). As scholars point out the challenge for smart grids is the *involvement* of energy consumers (Bigerna, Bollino, & Micheli, 2016; Gangale, Mengolini, & Onyeji, 2013). For involvement to occur; acceptance is required (Ellabban & Abu-Rub, 2016, p.1293). Specifically, to support an accelerated transition that is 'manageable', this implies an understanding of factors that relate to acceptance, because acceptance is a crucial final step for successful implementation of a feasible technology.

In this paper, the precursors are recategorized in a way that fits with the case study and can relate to a potential network-led *intervention* (i.e. an intervention is 'manageable'), or conversely, whether the precursor is 'unmanageable' by network-utilities and relating to *psychological* factors. The rest of this section reviews the scholarship that are perceived as precursors of acceptance that firstly relate to various somewhat *manageable* aspects of engagement, participation, and agency, and then secondly, the somewhat *unmanageable* (*psychological)* aspects of perceptions attitudes and trust. Thirdly, acceptance is discussed, and then definitions are provided.

5.2.1 Engagement, participation, and/or agency

Academic and industry focus on smart grids has explored engagement, participation, and/or agency in relation to smart grids (Abi-Ghanem & Mander, 2014; AEMC, 2017a; Burchell et al., 2016; Chilvers et al., 2018; Energex, 2017a; Gangale et al., 2013; ISGAN, 2017; Lopes et al., 2016).

Chilvers et al. (2018, p.203) describe participation as related to agency and engagement. They argue that customers must be involved and educated as a priority, to avoid disengagement. Gangale et al supports this position and assert that without consumer education and engagement, benefits of smart grids will fail to be realised (Gangale et al., 2013, p.622).

Consumer engagement is impeded with increasing complexity. This is demonstrated in a Portuguese smart grid study of 1084 participants, where 71% surveyed indicated they would purchase a device that would automatically control their electricity use if the tariff became overly complex; in particular 'if [the] tariff changed every hour' (Lopes et al., 2016, p.239). Importantly this indicates a type of outsourcing of complexity – of reducing the participant's agency — or expressed differently: this is *agency is traded for reduced complexity*.

This paper suggests that previous scholarship closely ties engagement with participation and agency — whereby all three terms imply an *active* involvement by the consumer within the energy system; including energy behaviour change (e.g. shifting consumption). This paper does not investigate behaviour change because an *automated* grid reduces *actual* behaviour change. In this sense behaviour change can be thought of as being substituted with agency.

5.2.2 Perceptions, attitudes, and trust

The effect of perceptions and technology was explored in-depth with the benchmark conceptual work of Davis (1985) on his 'Technology Acceptance Model' (TAM), which was originally designed for the challenge of acceptance of computer technology in the workplace in the 1980's. The TAM considers 'perceived ease of use', 'perceived usefulness' and 'perceived risk' that lead to a likelihood of an 'intention to use' a new technology. This concept, in a similar form (Risk Integrated-TAM, or RITAM) has already been applied to the smart grids (Ellabban & Abu-Rub, 2016; Park, Kim, & Kim, 2014). Both (TAM and RITAM) are based on perceptions and intentions (using surveys and not based on experience), whereas CONSORT is an empirical study of *actual* (rather than intended) use; so, although this is an important concept it is not explored further here.

There appears to be growing interest in understanding consumer perceptions of batteries and smart grids (ARENA, 2015b; Ginninderry, 2017; Mah, van der Vleuten, Hills, & Tao, 2012). During times of uncertainty, such as structural changes to the energy sector, scholars have highlighted that *trust* becomes increasingly important (Bellaby, Eames, & Flynn, 2010) and *'perceptions of end-users are a key factor for adoption of this technology'* (Ponce, Polasko, & Molina, 2016, p.587). Pivotal to energy transition is the concept of trust and importantly Gangale et al identify that *'when people know little about a technology…acceptance may mostly depend on trust in the actors responsible for the technology'* (Gangale et al., 2013, p.626).

Further, Büscher and Sumpf (2015) find that public involvement in a sociotechnical transition requires trust *more* than it does education (Büscher & Sumpf, 2015, p.2) because, *'everyday social life needs a "reduction of complexity" to get things done; it needs "voluntary blindness"'* (*ibid, p.2*) and that eventual acceptance may not lead to more active engagement, but a 'passive tolerance' (*ibid*). They define trust as a *'mechanism of complexity reduction, because it enables action despite uncertainty about the future'* (*ibid*) and as a 'necessary *precondition for actionability'* (*ibid*). Hence, trust is one of those critical preconditions for actionability, or transition.

Büscher & Sumpf argue that lack of knowledge is a serious barrier for smart grids; *'the problem of non-knowledge about the behaviour of smart grids may progressively become the most significant issue for all involved'* (Büscher & Sumpf, 2015, p.3). In terms of deploying smart grids, the first hurdle from a network perspective is the '*technical* operation…if it works' and second; the '*social* operation as communication' (Büscher & Sumpf, 2015, p.4). This social operation is underpinned by uncertainty. They argue that 'successful communication is, first and foremost, *unlikely*.' (ibid, p.4, original italics).

In summary, this existing scholarship points to the ability of trust to empower behaviour that involves some risk and uncertainty (Davis, 1980; Buscher & Sumpf, 2015; Gangale et al., 2013). The study by Büscher & Sumpf highlights this pivotal interaction between risk, uncertainty and trust. They discover that '*trust reduces complexity and thus enables action under future uncertainty…[and]… non-knowledge'* (Büscher & Sumpf, 2015, p.7).

Thus, the scholarship leads us to an understanding on the effect of an IoT technology (smart grids) and the responses from individuals in terms of agency and trust. Considering that smart grids are an IoT phenomenon, the level of agency required is likely lowered through automation, but this requires trust. Trust is the *mechanism* for trading agency for complexity — the key for reducing complexity is to accept the automatic operation and a lower level of knowledge in the system than is required to operate it at an individual level. Further, existing scholarship indicates that [with smart grids] consumer trust is required more than education, due to the level of complexity.

5.2.3 Acceptance (use or deployment)

The above discussion helps us understand the *precursors* or *preconditions* of technology acceptance. Scholarship of technology acceptance is well developed in terms of recognising that consumer acceptance is pivotal to technology implementation success or failure, regardless of the merits of the technology (Noll, 1992). Researchers have investigated consumer acceptance of smart grid development as a key for successful deployment (Hess, 2014; Toft et al., 2014; Wolsink, 2012). Critically however, the link to acceptance is very often tied to (active) consumer engagement and participation (ACOLA, 2017, p.71; ARENA, 2019a). Whilst this is acknowledged, a key element was left under-explored; namely what leads to acceptance and how those precursors may interact from a systems perspective.

Based on the thematic approach for this paper, finessed definitions are presented in subsection 5.2.4.

5.2.4 Re-defining engagement, agency and trust as pre-cursors to technology acceptance

The themes detailed above provide a list of *precursors* to technology acceptance. These are finessed according to the scholarship and findings from our empirical case study (CONSORT), as follows:

1. ***Engagement*** — this is a general term that refers to ***communication and level of responsiveness***, including education, between prosumers and other smart system agents such as utilities or network providers or retailers.

2. ***Agency*** — for the purposes of this paper, this refers to the level of ***control*** the consumer has or would like to have over their smart battery system. So, in this case, the smart battery system is the object subjected to some level of control or agency; by the prosumer or agent.
3. ***Trust*** — this is the condition whereby the consumer behaves and acts as with a sense of ***good faith*** that the system will function, and ***operate in the consumers best interests***, regardless of their level of knowledge; and by 'suspending' perceived risk.
4. ***Acceptance*** (use)— this is a general term that refers to consumers' decision to ***engage, or passively allow or tolerate*** the new technology. Acceptance, as evidenced in the scholarship is a marker for where consumers can transition to prosumers, (whether they are 'set and forget' or high agency) within smart grids. This is the goal of the network, as it indicates a synergetic operation with the prosumer that is beneficial for the function of the network.

These four categories were used to clarify the themes of analysis for participants responses (Section 4). Before turning to this analysis, the research methodology is first set out below.

5.3 Methodology and approach

The research approach comprised interviews with CONSORT participants and related stakeholders, case study learnings; a literature review; and an analysis of emerging themes and the re-categorisation of themes from both the case study and scholarship.

This study drew on CONSORT interview data from householders that were collected as part of the larger CONSORT social science research between November 2016 and July 2018. Twenty-one semi-structured interviews were analysed in total for this paper. Fourteen of these were CONSORT participant household interviews which were conducted by the lead author between November 2016 – December 2017, and were conducted prior to battery-system installation, and post-installation. These interviews were selected for analysis based on discussion of agency, acceptance, trust and engagement during the interviews. The other seven interviews were undertaken with CONSORT research partners, regulators and energy policy experts. CONSORT partner and expert interviews were carried out by the lead author between February 2017 and July 2018. All interviews were audio recorded and transcribed, with data management under the regulations of ethics committee approvals H0015886 and H0016022.

The process of integrating empirical and theoretical learning was iterative, and throughout the study (2016-2019). Theoretically, the case was not a neat fit into the literature because the scholarship either focussed on one or two aspects of the case under study, or conflated the aspects we wished to understand (i.e. this study separates engagement and agency). This mapping of concepts as the approach is in Table 5.1 provides the basis for a consistent analysis between the case study and the scholarship. The approach was divided into macro (general) and micro (householder) and the themes are divided into types of source types (scholarly, non-scholarly and case study). Overall, the focus of this study was exploratory in scope, and was to assess reactions and understandings relating to the themes being present rather than absent. Consequently, further thematic investigation did not focus on interviews where data was weak or inconclusive.

<table>
<tr><th colspan="5">Precursors to technology acceptance, themes and approach to the study</th></tr>
<tr><td rowspan="2">Pre-cursors to technology acceptance— macro level approach</td><td colspan="2">Existing scholarship
[Academic Researchers]
(References as per Table 1)</td><td>Non-scholarly/ Government reports
(References as per Table 1)</td><td>CONSORT Case study
[CONSORT researchers, pilot partners, external interviewees]</td></tr>
<tr><td colspan="2">Theme 1 (grouped) Engagement*, Agency and/or participation.
(Bigerna et al, 2016; Gangale et al, 2013; Abi-Ghanem and Mander, 2014; Burchell et al, 2016; Chilvers et al, 2018; Lopes et al, 2016).

Theme 2 Perceptions, attitudes, and trust
(Davis, 1985, Ellabban & Abu-Rub, 2016; Park et al, 2014; Ginninderry, 2017; Mah et al, 2012; Bellaby et al, 2010; Ponce et al, 2016; Gangale et al, 2013; Buscher and Sumpf, 2015)</td><td>Theme 1 (grouped) Engagement*, Agency and/or participation.
(AEMC, 2017; Energex, 2017; Ginninderry, 2017; ISGAN, 2017)

Theme 2 Perceptions, attitudes, and trust
(ARENA, 2015, Ginninderry, 2017)</td><td>Theme 1 Engagement*

Theme 2 Agency

Theme 3 Trust</td></tr>
<tr><td>Acceptance</td><td colspan="2">Theme 3
Acceptance/ use
(Hess, 2014; Toft et al, 2014; Wolsink, 2012; Ellabban and Abu-Rub, 2016).</td><td>Theme 3
Acceptance/use
(Finkel et al, 2017; ACOLA 2017, p.71; ARENA, 2019)</td><td>Theme 4
Acceptance/use</td></tr>
<tr><td rowspan="2">Micro approach</td><td colspan="4">CONSORT case study</td></tr>
<tr><td>Householders</td><td colspan="3">Information, understanding, bill savings, ease of use, performance, risk (such as cost), agency, lack of agency, institutional listening, and others.</td></tr>
</table>

[*engagement includes information provision]

Table 5.1. Precursors to technology acceptance, themes and approach to the study.

The case study analysis is now applied using the categorization in Table 1, whereby engagement and agency are separated out.

5.4 Results: CONSORT smart grid case study

The findings are related here according to the precursor themes in Table 1 that are understood to influence the acceptance of a new technology. Hence, this section presents findings in the following themes 4.1. Engagement, 4.2. Agency, 4.3. Trust, and 4.4. Acceptance.

5.4.1 Engagement (encompassing information)

When it came to the amount of information and engagement provided and how much understanding the participants had, CONSORT participants related a range of participant experiences and responses, from satisfaction through to frustration.

Householder comments in interview relating to engagement and information often acknowledge the benefits of more information for understanding, for example —

> **A:** Well, it's immediate knowledge. You can see on a day to day, or an hour to hour basis what's happening.

(Participant BT136, Oct 2017)

Participant BT140 was very satisfied with their level of understanding and information provided —

> **A:** It's telling me what it's costing me a day, which is good. And some days we've actually gone into credit which is even better, but how that fits with our power bill I'll probably have more of an idea once we get the bill.
>
> **Q2:** That improved your understanding of your energy use?
>
> **A:** Yeah, definitely.

(Participant BT140, Nov 2017)

However, many participants felt frustrated by a lack of information and engagement during the pilot and expressed a desire for more, but simpler information. For example, participants BT112 said they would like to see a 'set and forget', *'Solar for Dummies Guide*.'

Similarly, BT111 would have liked more communication and understanding responding to various areas of information provision —

> **Q2:** do you find it accessible and easy to understand?

A: Yeah, I think once we worked out what the different things were. There's more information on the website than there is on the app. Once I realised that, you could get more information if you needed it.

(Participant BT111, Sep 2017)

Between 2016 and 2019, engagement by the CONSORT wider team was conducted via email, in-person information sessions, academic and industry focus groups and academic (research) interviews, one of which was a site visit. In addition, an interactive 'participant portal' or internet chat room was introduced during the pilot, for the purposes of increasing understanding and communication with the intention of supporting people learn about the new technology. As of June 2019, the forum had a total of 81 topics (generally economic and technical); and 227 replies. However, it was found that a few participants dominated the forum, and not all participants logged on. Seven participants posted during the forum history, or approximately 20% of the pilot cohort were proactively engaged.

An interview with the TasNetworks Customer Engagement Advisor highlighted the need for increased engagement and information sharing —

> 'if there is clarification potentially that I can send out to the participant group as a whole [via email] then I think that is something we should do, because overall, we need to make sure the customer has a good experience and that they are going to get maximum benefit from the system'

(Customer Engagement Advisor, TasNetworks, Interview May 2017)

In terms of engagement and information the CONSORT case, there were a range of participant experiences from the satisfied through to the frustrated, when it came to the amount of information provided and the level of participant understanding. TasNetworks intervened after the first year of the pilot (creating the portal) to help improve communication. This method allowed knowledge sharing and gaining trust through a *transparency of communication*. This is argued to be key, because asymmetry of information is seen as a significant barrier.

5.4.2 Agency

On the theme of agency, the study found a range of responses, from an experience of frustration at lack of control (i.e. agency) over the system, to those that were closer to a 'set and forget' mindset. Most participants expressed a desire for increased agency or control of their system — to be able to over-ride the software, or to 'charge on demand'. However, from the installer's perspective, although greater control is available, it is more difficult to manage and keep safe. In other words, though a ‘manual option’ exists, the complexity is high, and the software is programmed to ensure the economic benefit for the householder. Installers suggest that although the option of greater agency is available, that non-electricians should avoid ‘mucking around’ with the systems. However, interviewees from the business sector (Reposit; and Moreland microgrid (Cox, 2017)) suggest that agency comes down to consumer choice. It is argued that choice drives the brand selection which may offer differing levels of agency, from low to high.

An example of a low-agency participant —

> **Q:** And do you feel comfortable using the technology?
>
> **A:** Well there's nothing we have to do. I mean if there was a problem of any sort, the only thing I know how to do is to shut the system down, and I'm comfortable with knowing how to do that, but there's nothing else that you have to know really. It's just a sort of set-and-forget thing as far as I can work out.
>
> **(Participant BT136, Oct 2017)**

Others wished for higher agency. A common example of frustration was the desire to ‘charge on demand’ —

> **A2:** And they charged up the batteries. So now we can’t do this. We can’t say to the battery, “We want you to charge over the next three hours.” But TasNetworks can. So - they recognise that peak power’s coming along. They charged it up and then pinched it back out again.
>
> **(Participant BT132, July 2017)**

Again, a frustration at a lack of agency —

> **A:** I can't override it to say, please charge my battery up tonight, so that’s a bit disappointing. All it is, is a viewing app. It doesn't give you any control. I don't know, unless the new version is going to be upgraded so you can.
>
> **(Participant BT104, May 2017)**

An understanding of agency from the battery installer’s perspective is well understood. In interviewing the research partners, some of the greatest insights about the interaction of agency and trust came from the installers. When asked about the lack of a ‘charging on demand function,’ one installer business general manager responded —

> ‘the homeowner [is] … able to charge their battery overnight ... So that sort of control is definitely able to be done. The thing with the Reposit, and this is what people don’t understand… it makes

> decisions…to make sure the homeowner is always winning—so the reason you can't change anything with Reposit is because, there is nothing to change. It does the thinking for you.... But there are other batteries where you will have those sorts of manual options'

(Installer, Interview Dec 2017)

When questioned about those participants that seem more interested in back-up and less about the economic aspect, and the wish for a 'hoard button' or different depth of discharge, and if this is possible, the installer replied —

> 'we can set the battery reserve to whatever we want, we can set it to 100% if you wanted to, but you'd be silly to, but you could…So, all that stuff is available'

(Installer, Interview Dec 2017)

In summary, it is not beneficial overall to 'override', because of the technical and economic solutions it is designed to provide for both TasNetworks, their customers, and the pilot objectives —

> 'the less people muck around with it the better…everyone thinks they're an expert… there's a lot of settings that … [are] not really stuff that should be touched'

(Installer, Interview Dec 2017)

A TasNetworks engineer describes a higher agency for customers with some other battery management software brands that would have brought about a different type of pilot, as other brands may have —

> 'different philosophies… [and offer] …different amounts of control [agency]'

(TasNetworks engineer, Interview Feb 2018)

Agency is part of the Reposit business model according to a Reposit manager —

> 'at the end of the day the customer is going to want to be able to choose …the installer…the hardware …the retailer … so I absolutely think a key of this is…facilitating and enabling consumer choice in giving them the opportunity to choose the products and technology which are best for them'

(Business Development Manager, Reposit, Interview, Feb 2018)

It was recognised within another ARENA project investigating consumer perceptions of smart battery systems with a survey of 200 people, that the technical solution may be feasible, the systems may be economic, efficient, and beneficial but a main sticking problem is lack of a business model for a distributed market and that —

‘in a sense it’s like a simple consumer choice …one of the key aspects is to gauge desirability…[because]…people are the biggest issue.

(Program Coordinator, Moreland Microgrid, Interview 7 Feb 2017)

To summarise, it can be said that some participants expressed a desire for increased agency over their system — to be able to over-ride the software, or to ‘charge on demand’. However, from the installer’s point of view, although greater control is available, the complexity is high, and the software is already designed to make sure the householder benefit. The installers suggest that although greater agency is available, that it is not beneficial — that people should leave the battery operation to qualified electricians (installers). It is argued that this choice (i.e. agency) is exercised in selecting the brand of battery management software with its’ *philosophy of agency* and level of agency it offers.

5.4.3 Trust

Interviewees revealed that where cost savings were obvious to them, it was linked with trust, and where there was an attitude of ‘set and forget’ towards the new system, that this was generally accompanied by a level of implied trust. Trust may also be multi-layered. Trust could be assigned to the battery operation itself, trust could be assigned to the installer, and yet trust might be lacking with service providers more widely. Crucially, building trust during times of change and uncertainty is understood to be a key to acceptance. Overall, trust leads to acceptance.

Here trust was multi-layered; BT116 trusted the installer, that the battery was working in his best interests, but did not trust the service providers —

A: I don’t think I’d trust it. These contracts we sign about they are only for 12 months and then suddenly they can change it can’t they? That’s the drift I have picked up.

(Participant BT116, Jan 2018)

An example of the visible link of cost savings with trust —

A: I just didn't feel adequate to be able to assess and compare things on my own. I was happy to be guided by somebody that I thought I could trust … Like if you can trust the app and what it tells you are the costs … I mean if it maintains that we'll be more than happy

(Participant BT136, Oct 2017)

And again, what leads to success is building trust during uncertainty and understanding consumer expectations, according to the head of the Australian Energy Regulator—

> ‘it’s from fear…people are more likely to be negative through uncertainty…it goes to this trust and agency stuff as well …we’ve been doing quite a bit of work in behavioural insights…’
>
> **(CEO, AER, Interview, July 2018)**

The following expert interviewee describes trust in a new system as the process of ‘building a reputation’ —

> ‘this is a perpetual problem with any new technology… eventually people build up a reputation…the market model is actually where it is going to go’
>
> **(President, Smart Energy Council, Interview, July 2018)**

A partner describes trust and transparency within the pilot —

> ‘I think it [the participant forum] helps with trust as well…it’s removing a barrier from people learning from each other… I think helps with the open and transparent sort of approach to it all. Like, we’re not hiding anything if we’re giving them the ability to communicate in front of everybody else.’
>
> **(Customer Engagement Advisor, TasNetworks, interview May 2017)**

Overall, interviewees revealed that where cost savings were visible it was linked with trust, where there was an attitude of ‘set and forget’ that it was accompanied by trust, and that trust is multi-layered. Trust could be invested in the battery operation itself, trust could be assigned to the installer, and yet trust might be lacking with service providers. Crucially, building trust during times of change and uncertainty is seen as a key to acceptance.

5.4.4 Acceptance (use/deployment)

Regardless of satisfaction or frustration with the technology, most pilot participants accepted the technology. Further, the acceptance seemed to be regardless of whether they were interested in high agency (control) or low agency (set and forget). To some extent initially, the participants were predisposed to acceptance because they had elected to be part of the pilot and committing approximately 15% of the costs toward the battery system (a minimum of AU$2,000). However, the social researchers quickly found that householders in general felt they needed more information to be provided and wanted more control. They wanted to have the installers explain the system to them, and the social researchers soon became conduits to facilitate the problem solving between the householders and the network utility or the software firm. The additional layers of engagement provided by UTAS and TasNetworks for the pilot was critical, however, it was still seen by many participants as insufficient.

However, an example on the positive side of acceptance, one participant responded —

Q2: How is that performing since they were installed?

A: Brilliant…Now, if you go and put in a spa or a bathroom worth 20,000 or 30,000 that's all you're going to get, a bathroom. Here, if I invest $30,000 it gives me a return, it's like having money in the bank …[But] I'm not there watching every little minute of it. I've got more important things to do with my life unfortunately.

(Participant BT125, Nov 2017)

For the instance above, acceptance relates to economic and technical aspects of the smart-battery. Acceptance is the theoretical end-point of this paper, with the focus on the 'precursors' of acceptance now summarised:

The role played by *engagement* and information was indicated by the range of participant experiences from satisfied to frustrated, in terms of information and engagement. The TasNetworks private participants' forum, in addition to the social science research and interaction, was likely facilitative for communication and understanding and for trust.

The role played by *agency* was evidenced by participants expressing a desire for increased agency in some instances —however, the ability of customers to 'muck around' with a system is seen as undesirable by installers. Consumer choice (a form of agency) is seen as the power to choose one brand over another which may offer differing levels of preferred agency. In other instances, agency was not desired, and a 'set and forget' system would be preferred — and this is a trade of agency and trust.

The role of trust is that it leads to acceptance, and interviewees revealed that visible cost savings was linked with trust, and that trust is multi-layered. Crucially, building trust during times of change and uncertainty is seen as a key to acceptance. Building trust in the energy system during times of structural change is at the centre of these findings.

5.5. Discussion

It is seen that *trust* in the agent that controls new technology behaviour, *reduces complexity*; however, in doing so it is argued that it trades away some *agency* over a system, such as 'charging or saving on demand' with the battery system. Thus, from an overall energy system perspective, a balance arises between a level of trust *and* level of agency, from the prosumers experience. This was indicated through participant interviews and supported by existing scholarship. For a network-led, stable and managed system transition to more distributed storage, it is argued that the network or utility requires a higher level of *engagement* with consumers about new technologies such as smart batteries than currently exists. TasNetworks provided an example of this when they introduced an online participant portal after the introduction of the new technology. Nuanced engagement forms a pathway for consumers to interact beneficially with the information to decide on a level of agency, which then may be somewhat manageable by network and utilities.

5.5.1 Proposed technology acceptance process

Agency and engagement (or participation) are responses of householder to new technologies, or new systems of operating. One aspect for consideration is what level of participation and agency *might consumers wish to have* with the battery system, or whether an option is exercised to trade this agency for reduced complexity (a service provided by an unknown player in the energy system at present). We argue that agency is a form of decision-making that has an element of trust or reliability that can lead to acceptance of the technology.

In brief, it is proposed that *agency* and participation *include decision-making and choices*, based on substantive or customised information is expected to be a *pathway for trust* for the consumer, (at least theoretically; and in practice the methods are likely more complex). Nevertheless, once a consumer *trusts* the battery system then there is *acceptance* of the new technology. An addition to the technology acceptance process proposed in this paper, is the mechanism that describes the balance: *'agency traded with trust to reduce complexity'* which is illustrated below in Figure 5.1.

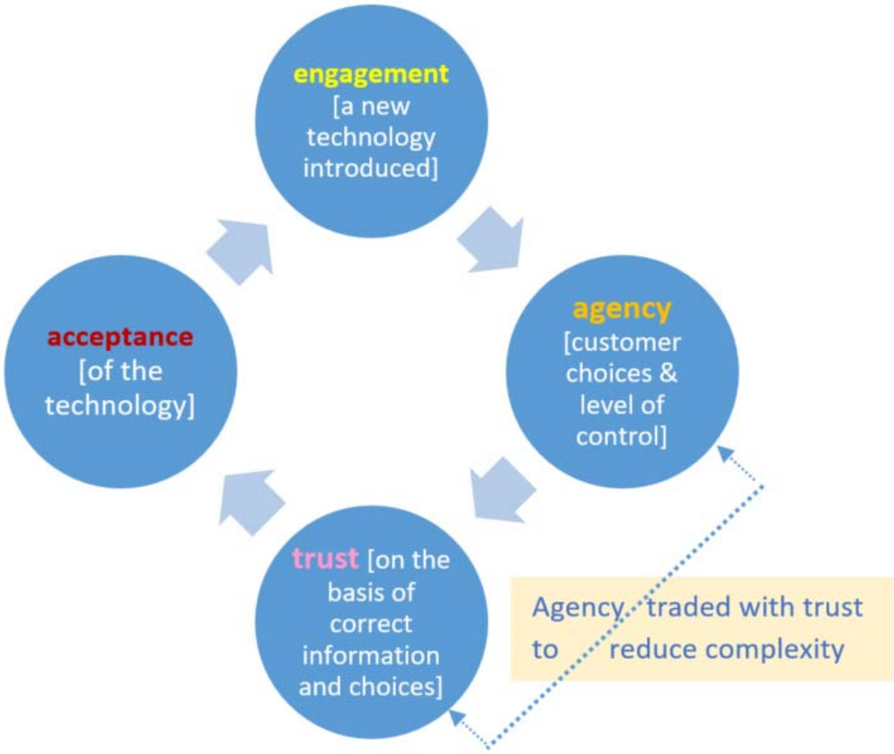


Figure 5.1. Heuristic of technology acceptance — with agency and trust in a two-way flow of 'tradability'.

Clarification of this heuristic/process in more detail from the network-perspective, and suggestions about how to reach acceptance, are outlined as *phases* in Table 5.2 below.

Engagement (Phase 1)	***Agency*** (Phase 2)	***Trust*** (Phase 3)	***Acceptance*** (Phase 4)
Engagement and communication by 'grid' (i.e. network/utility/service provider) with consumer.	Agency Grid offer customized level of agency to the consumer.	The consumer has a leap of faith and trusts the grid system to operate partially autonomously on their behalf at an agreed level of agency.	Consumers may successfully transition to a smart grid, either actively engaged, or passively tolerant to the new technology.

Table 5.2. Enabling conditions for the acceptance of a new technology such as smart grids

5.6 Conclusions

In this paper, based on the CONSORT case, we proposed a theoretical process for new technology acceptance in energy consumers for an electricity transition, based on engagement; agency and choice; and trust. This approach was at the network-level and the bringing together of existing ideas in a new way is supported both through existing scholarship as well as the empirical research on

CONSORT. This heuristic is the considered response to the research question on what the conditions to consumer acceptance of a new technology are? — from a network perspective this should be somewhat manageable (governable).

In response to the second research question, how might the enabling conditions be related in a way that assist utilities and prosumers to accelerate a transition? Figure 1 illustrates how the acceptance precursors are related in terms of a process; and it is suggested as an idealised management process for network-utilities.

This paper provided evidence, supported through the case study and the literature for a type of exchangeability of *agency for trust* in cases of high *complexity*, and during socio-technological system change. It is asserted that this 'exchange' is likely to be beneficial for both networks and prosumers. It is reasoned to be beneficial for achieving a stable, safe, smoothly governed transition, and reduced complexity from the prosumer perspective.

Although some consumers may *currently* express a desire for more agency, by contrast, prosumers may desire reduced complexity *even more so*. Overall, this is suggested to be achieved where high levels of transparency of battery system operation are provided for the prosumer.

In brief, first, we find that prosumers require higher levels of tailored information; second, we find that prosumers do not always desire greater agency; and that third, trust is 'tradeable' for agency and may be more impactful than education in a 'smart' IoT grid.

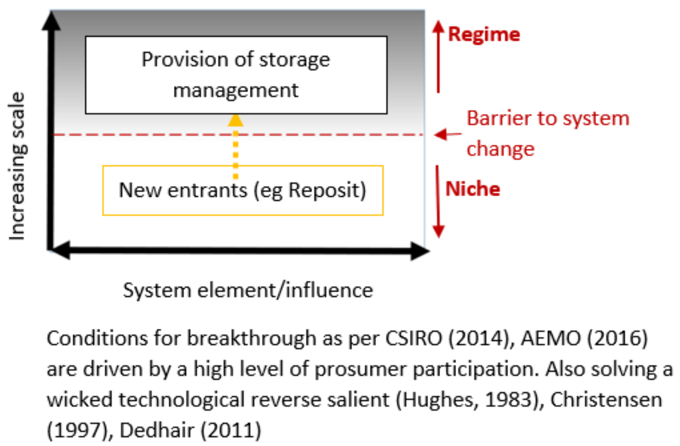
A contextual lens and outline for the chapter ahead, Chapter Six

This outline introduces the paper ‘The evolving role of battery system installers within a transitioning electricity sector’ that is in the place of Chapter Six, which is submitted and is currently under review with revisions requested, with the journal ‘*Environmental Innovation and Societal Transitions*’. This outline provides the lens and context with which to view this paper.

Empirical material this paper drew upon was interviews with participant householders, five installers (including work shadowing of two), and other CONSORT project researchers.

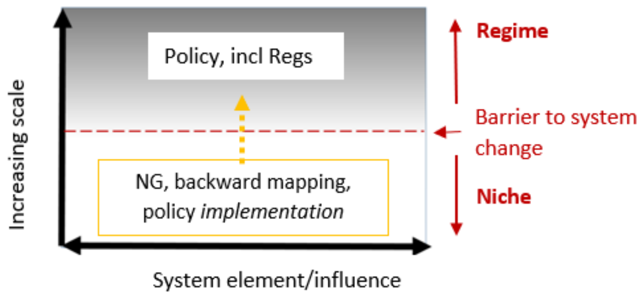
The research question that this paper addresses is in relation to upscaling, analysing *how innovation intermediaries may evolve post-disruption* by drawing on policy implementation scholarship. That is, theoretically, what is reasonable to expect once a socio-technical system stabilises and matures? And, ‘What future might be envisaged with respect to orderly governance and policy implementation; with respect to the installers role?’

The theoretical position of this paper is most closely aligned to three aspects of ‘niche conditions that contribute to innovation breakthrough’ described in Chapter Two, that is: 1) the effect of new entrants into the energy system, 2) the effect of policy implementation and 3) impact of consumers driving change. The schematic below describes the influence of new entrants into the energy market (creating offshoot industries and potentially addressing current storage problems or ‘reverse salients’ as outlined in Chapter Two)



Niche conditions that contribute to innovation for breakthrough, Schematic D

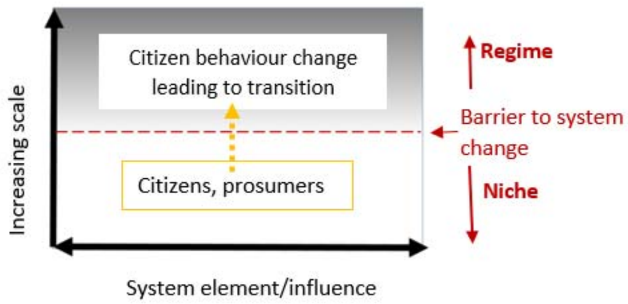
The key theoretical contribution of this paper is the effect of backward-mapping policy implementation, whereby the new workforce type evolves from new entrants. This situation of new entrants will eventually stabilise into competent street-level bureaucrats as briefly explained in Chapter Two and extended in this paper. Backward mapping and bottom-up policy implementation is suggested to enhance innovative breakthrough as per the Schematic B below.



Conditions for breakthrough as per Elmore (1979), Fiorino (1997), Voss et al (2009). Where policy development = implementation

Niche conditions that contribute to innovation for breakthrough, Schematic B

Again, the schematic below simply acknowledges that potential prosumers are central to change and implementation. Pilot participants are an example of real-world potential prosumers.



Conditions for breakthrough as per CSIRO (2014), AEMO (2016) are driven by a high level of prosumer participation

Niche conditions that contribute to innovation for breakthrough, Schematic C

The concept of citizens driving change is central theoretical aspect, and a strong theme of the thesis. This concept is discussed and supported by CSIRO (2014), AEMO (2016) and Simhauser, P., & Nelson, T. (2012) due to the high level of participation of consumers in the energy market, which started as solar PV and has an increased potential due to smart batteries. Further, although the pilot was instigated by industry, it did not preclude learnings from the participating householders, in terms of their status as prosumers.

Hence, this paper may be viewed through the lens of policy implementation, that includes the elements of 'new system entrants' and 'citizens driving change', as key factors that may accelerate a socio-technical systems transition.

Chapter Six

The evolving role of battery system installers within a transitioning electricity sector

Abstract

This paper focuses on the pivotal role of smart battery installers within an electricity sector transition. It draws an Australian smart grid pilot and examines policy implementation scholarship alongside socio-technical systems theory in order to better understand installers. This paper argues that installers have innovative (intermediary) skills in an unstable transitioning energy policy environment and are complemented by their adaptive Street-Level Bureaucrat (SLB) skills in circumstances of a stable system or policy environment. The research finds that best-practice installers act like SLBs, and their role offers important insights into the linkages between technology innovation and policy implementation. SLB installers are well positioned to close the implementation gap within installation processes by developing new-system competencies and standards. This study suggests increased policy attention on installers could advance the aim of orderly governance during a time of disruption, supporting the transitioning role of installers from solar PV technicians to IoT experts.

Keywords: Innovation intermediaries, Street-Level Bureaucrats (SLBs), Residential battery installers, Electricity system transition, Distributed energy storage.

6.1. Introduction

6.1.1 Accelerating change in the Australian electricity sector

The disruption to Australia's centralised energy system is being driven by the high rate of solar photovoltaic (PV) installation, largely within the residential sector (OECD 2019), as well consumer demand and costs that are falling regardless of policy settings (AEMO, 2018). These factors are driving decentralisation and behind-the-meter residential storage, which promises to further transition and stabilise the grid. Whilst planning is underway to smooth this transition, it is not uniform, and technology innovation is accelerating whilst policy lags behind (AEMO, 2016; COAG Energy Council, 2019; Finkel et al., 2017). There is recognition by the Australian government of the need for an 'orderly' governance and system transition (Finkel et al., 2017, p.4), given previous policy implementation failure in government programs related to energy (Shergold, 2015) , and so this paper engages with the concept of an orderly transition with a focus on the critical role of the installer for implementation success.

Battery storage is acknowledged as a significant and emerging technology in a rapidly shifting landscape. However, to date there has not been much attention to the role of installers (AEMO, 2017b). In this paper the role of installers as innovators in a transitioning energy environment is therefore examined. It is argued that installers vary in type, and propose a two-fold classification: first, installers that predominantly have intermediary skills in an *unstable* environment, as conceptualised within science and technology studies; and, second, installers who are more focused on the changing policy context and who have adaptive street-level bureaucrat (SLB) skills, as conceptualised within policy implementation scholarship.

The aim is to examine how innovation intermediary roles might adapt post-disruption. The policy implementation scholarship is explored to understand the installers role in a post-disruption phase.

6.1.2 Context of the present study

The scope of this paper is to examine the grid-connected, storage sector in Australia with a case study focused on a residential smart battery trial on Bruny Island, Australia. Australia leads the world in deployment of small-scale, residential battery storage capacity (Porteous et al., 2018), and is forecast to reach 30% of global demand for residential storage installations by the end of 2019 (BloombergNEF, 2019), installing 70,000 batteries in 2019 alone (Maisch, 2019). Globally, so called 'behind-the-meter storage' grew to almost 2GW in 2018 (Munuera & Toril, 2019). The *Australian Energy Market Operator* (AEMO) forecasts Australian battery storage installations will reach 5.6 GW by 2036 (AEMO, 2019).

This paper forms a qualitative investigation into the role of battery system installers within the context of this rapid technological change in the Australian energy sector (COAG Energy Council, 2019). The installation of residential battery storage systems, hereafter referred to as 'Distributed Energy Storage' (DES), has been supported by a number of different government policies, both at the state and federal level; see for example (ACT Government, 2019; Government of South Australia, 2019). Within a system transition, the socio-technical systems literature, in general, has identified the role of innovation intermediaries as facilitators; spanning individual agents, to organisations, and knowledge services (Howells, 2006, p.718). This paper focuses on a type of intermediary that is crucial in DES implementation: the battery installer.

Energy transformation is recognised to be highly complex, due to the pace of technological change and the difficultly faced by policy makers and standard setters in keeping up to date, for example in DES software integration. Thus DES installers are facilitating change technically but they are working in circumstances where the relevant standard, AS/NZS 5139:2019, remains in draft (CEC, 2018a; SAI Global, 2017; Standards Australia, 2019), and where significant implementation gaps exist, particularly at the interface of electricity and ICT/IoE (Information-Communications Technology/Internet of Energy). The IoE in this context refers to a 'web-enabled Smart Grid system' (Bui, castellani, Casari, & Zorzi, 2012) in which PV installers currently face, ostensibly, having to upskill from electricians to IoT experts, in terms of coordinating the smart battery components.

These difficulties were observed in a 3-year, multi-organisation, multi-disciplinary DES pilot case study CONSORT *(CONsumers providing cost-effective grid suppORT)* and are identified, conceptualised and explained in this paper. The CONSORT project comprises 34 smart-battery households acting as a Virtual Power Plant to support an undersea cable from Bruny Island to mainland Tasmania, Australia, at times of peak demand, described further below. It is argued that the pilot may be illustrative of larger scale implementation challenges facing the transitioning energy sector, that are compounded by the rapid growth of renewables and the lack of experience of many new entrants. Implementation is challenging, and so good policy design is crucial to avoiding unintended consequences. The CONSORT case study provided the opportunity to examine implementation practices and processes in action, through researching the installers of the DES and PV technology.

6.1.3. Aims and structure of the paper

This paper has two key aims: first, to apply ideas from policy implementation scholarship about Street-Level Bureaucrats to STS scholarship on intermediaries in order to better understand the different types and roles of installer intermediaries, positioned as they are at the intersection of technology innovation and policy implementation; and, second, through analysis of new empirical findings from a detailed case study to propose a twofold classification of DES installers, as either hybrid SLBs-intermediaries or 'classic' (traditional) intermediaries. This classification develops an understanding of how the role of DES installers might evolve as innovation processes stabilise and become more mainstream over time.

This paper is comprised as follows. Section 6.2 provides a review of socio-technical systems (STS) and policy implementation scholarship, with a focus on intermediaries, and street-level bureaucrats (respectively). These two distinct strands of scholarship are brought together by proposing a new conceptualisation of the relationship between sociotechnical system maturity and the evolution of intermediaries into SLBs. Section 6.3 describes the smart grid case study, methods and the technical, knowledge-diffusion role of the CONSORT installers. The findings from the case study are presented in Section 6.4, and discussion and conclusions are presented in Section 6.5. Next, the two areas of theory that aid the conceptualisation of the installer from a systems perspective are presented.

6.2. The roles of innovation intermediaries and street-level bureaucrats

6.2.1. STS scholarship — The role of innovation intermediaries

Systems theory is suited to investigating accelerating innovation during times of transition (Geels, Sovacool, Schwanen, & Sorrell, 2017) and we employ an STS perspective in examining and explaining new-entrant intermediaries to the Australian energy market and their role in accelerating the energy transition in part by addressing implementation gaps.

Much scholarly attention has focused on the question of how innovation intermediaries *accelerate* a sustainable transition (Bush et al., 2017; Gliedt, Hoicka, & Jackson, 2018; Hargreaves, Hielscher, Seyfang, & Smith, 2013). However, in this literature there is no acknowledgement or empirical analysis of policy implementation from a theoretical perspective, and thus currently no recognition of the policy concept of street-level bureaucrats (SLBs) (P. Hupe & Hill, 2007; Lipsky, 1969; Nothdurfter & Hermans, 2018; Tummers & Bekkers, 2014) in the socio-technical systems literature. This is despite the discussion within socio-technical systems literature on policy. What is established however, is that intermediaries assist in scaling-up innovation niches (Geels & Deuten, 2006), and include both individual actors and institutions (Bush et al., 2017; Geels & Deuten, 2006; Gliedt et al., 2018). An intermediary actor's key role is in 'consolidating, growing and diffusing novel innovations' (Hargreaves et al, 2013, p.868).

Innovation intermediaries have been described as system actors and policy entrepreneurs (Gliedt et al., 2018), 'middle men' of technology diffusion (Howells, 2006, pp. 715-716) and facilitators of knowledge (Bush et al., 2017). Battery system installers, as IoT niche-level businesses and actors are centrally placed to demonstrate their influence on a socio-technical system transition; and either to accelerate or hinder transition. However, we have identified the neglected role of installers as intermediaries with both (radically) *innovative* yet also (incrementally) *adaptive* skills capacity that are key to overcoming implementation issues of DES on a residential basis. By adaptive skills, this refers to the incremental innovation of SLBs, which are roles normally associated with public servants in stable institutional environments. Installers represent the critical interface between households and networks, so an understanding of the barriers to implementation that they encounter is arguably crucial to successful DES roll out.

A systematic literature review by Gliedt et al (2018) of all the scholarly publications on innovation intermediaries to mid-2017 — found that the definition of the roles of intermediaries is ill-defined and that they span scales and sectors. This review re-confirmed that innovation intermediaries play a key role in scaling up innovation. Moreover, innovation intermediaries (as policy entrepreneurs working in a high-risk environment) 'help create the conditions for scaling niche experiments – *during times of institutional uncertainty'* (Gliedt et al., 2018, p.1247, italics added). In this paper, we recognise the installers as innovative intermediaries and new-entrant entrepreneurs (transitioning from PV to smart-battery businesses) and facing institutional uncertainty.

In terms of accelerating innovation and transition, or "scaling-up," Gliedt et al note that knowledge sharing is critical (ibid, p.1255). Knowledge sharing by intermediaries, especially in online ICT platforms, has been identified as a possible key to scaling up innovative technologies (Geels & Deuten, 2006, pp.267-268 In Hargreaves et al, 2013, p.874; G. Smith & Akram, 2017). Intermediaries are described as 'actors that facilitate relationships between key actors and enable sharing and pooling of knowledge' (Bush et al., 2017, p.139). For this paper, the focus is on innovation intermediaries in the classic sense, as actors — applying the case of battery system installers.

Parag and Janda (2014) assert that effective agents for change mediate from the middle — as a policy concept between the top-down and bottom-up policy implementation. As mentioned in Chapter Two, the bottom-up versus top-down debate around innovation is a concept that has been superseded by the theorists known as 'the Synthesizers'(namely, Barrett, 2004; Elmore, 1979; Fiorino, 1997; Hjern & Porter, 1981; Koontz & Newig, 2014; Sabatier, 1980). Parag and Janda (2014) outline a concept of 'middle actors', and they rightly assign agency to these actors. However, they fail to recognise that actors that facilitate change within transitions (either termed intermediaries, or middle actors) can be individual actors and not only agencies and organisations (Parag & Janda, 2014, p. 104). Other scholars that developed this idea of a range of actor types include Bush et al, (2017), Geels and Deuten (2006) and Gliedt et al., (2018) (see Table 6.1). Hence, applying a policy framing, the installers are closer to a backward-mapping approach rather than a 'middle-out' framing. The middle-out framing is a hierarchical perspective of policy implementation that does not explicitly consider the issue of proximity to implementation processes. Given the central discussion of installers as innovation intermediaries, this area of scholarship on ‘middle actors’ was therefore not explored further.

As a general definition of a purpose, intermediaries are pivotal for implementation success that ‘resolves technological, regulatory, and business risks’ (R. K. Lester & Hart, 2015, p.48). The implementation process within pilots (experiments) has been described as one of ‘de-bugging full scale prototypes’ (ibid), and the unsolved administrative and technical problems that lead to pilot failure are what Lester and Hart define as the ‘demonstration gap’ or ‘good ideas going nowhere’ (R. K. Lester & Hart, 2015, p.49). Thus, a critical task is to devise an innovation system in which multiple pathways can be pursed and failure is tolerable. Failure is only tolerable where the value of learning is emphasised, and research pilots are an example of this. However, the longer-term goals must be to create an institutional structure that can accommodate and promote diversity, experimentation, and competition in the innovation process.

In summary, the specific roles and activities of innovation intermediaries are *not well-defined*; and they include private or public sector organisations (Kivimaa, 2014); ICT platforms or ‘knowledge infrastructure’ (Geels & Deuten, 2006, p. 268), organisations and individual actors (Hargreaves et al., 2013). Individual actors — as *a workforce type*, i.e. installers — are the innovation intermediary type focused on in this paper.

Socio-technical systems scholarship has established that ‘intermediaries’ are critical in accelerating system change. It is argued that, firstly, intermediaries are critically positioned to either accelerate *or* hinder system change. Secondly, this paper suggests that scholarship on intermediaries from STS literature is yet to connect with policy implementation (SLB) literature; whereby SLBs are also critical in implementing change. The second strand, SLBs within the policy implementation scholarship is now presented, before bringing both together for Section 6.2.3; and summarising the characteristics of innovation intermediaries and SLBs in Table 6.1.

6.2.2. Policy implementation scholarship — The role of SLBs

This section will argue that the success, or not, of policy implementation and the deployment of new technologies is vastly impacted by whether policy is being implemented through competent, sector-wide, bedded-down practices (roles typical of SLBs) or new-entrant businesses that are trouble-shooting, learning and innovating (roles typical of innovation intermediaries). The SLB, as a policy concept, provides an important insight for STS work, and innovation intermediaries in particular, because of their similarity in managing change and innovation; knowledge dissemination; and crucially, as facilitators or links between individuals and the system (or intended policy). In this sense both innovation intermediaries and SLBs can be considered as addressing the implementation gap between an ad-hoc disruption and a more orderly transition.

The term Street-Level Bureaucrat within policy implementation is a well-developed area of scholarship following the seminal work of Lipsky (1969) on classic case studies of SLBs including teachers and police. Lipsky defined a Street-Level Bureaucrat as a public servant constantly interacts with citizens as part of the role, and whose role has a significant amount of discretion or independence, and the 'potential impact on citizens with whom he deals is fairly extensive' (Lipsky, 1969, p.2). Street-Level Bureaucrats are employed within an established system (bureaucracy), with pressures of time, experience, autonomy, and professional discretion, that inevitably lead to decisions, outcomes and behaviours *that may divert from formal policy* (Gofen, 2014; Lipsky, 2010; Sevä & Jagers, 2013) within *established* institutional frameworks (Breit, Andreassen, & Salomon, 2017).

A 10-year systematic literature review of SLBs by Nothdurfter and Hermans (2018) reconfirmed that SLBs have the potential to inform 'responsible and accountable institutions' and that SLBs can have both positive and negative aspects of discretion in carrying out their roles.

Rather than policy implementation being understood as being directed from the top-down, as it was prior to the work of Lipsky (1969); with the assumption that SLBs having a low *discretion* for incremental or adaptive innovation; it is now widely understood that SLBs 'are an important source of innovation', despite having 'little formal authority to make programmatic decisions' (Maynard-Moody, Musheno, & Palumbo, 1990, p.833). Even so, their ideas are still often ignored by those in positions of higher authority (ibid, p.833). The central observation of Maynard-Moody et al is that SLB's discretion has an important effect on implementation success, summarised as: 'the program with greater street-level influence in policy processes was more successfully implemented' (ibid, p.845). Brodkin (2011) advocates 'management-by-enabling' as a mode to enhance positive implementation effects. In any case, 'wherever work is delegated, the delegating person loses some control…[and] actors may be faced with situations in which rules are ambiguous or even contradictory' leaving decision-making as a matter of the judgement and discretion of SLBs (P. Hupe & Hill, 2007, p.281).

Despite this, there may be a balance between the concepts of orderly governance and policy that can support current innovation intermediaries (installers), and the independence and policy-adaptative behaviour that SLBs demonstrate at the coal-face of implementation.

Table 6.1 below summarises the key characteristics of innovation intermediaries and SLBs from the scholarship as they pertain to individual system actors.

Summary of key characteristics of innovation intermediaries and SLBs in the scholarship

Key characteristics of innovation intermediaries within MLP/STS	**Key characteristics of SLBs within Policy Implementation**
Innovation intermediaries **accelerate** a sustainable **transition** as per Bush et al., (2017); Gliedt et al (2018); Hargreaves et al., (2013).	SLBs are an 'important source of innovation' as per Maynard-Moody et al., (1990).
Roles that assist in **scaling up niches** as per Geels & Deuten (2006).	SLBs are highly influential on *implementation success*[1] as per Lipsky (1969, 2010), Gofen (2014), and Seva & Jagers (2013).
Roles that span from **individual actors and institutions** as per Bush et al., (2017); Geels & Deuten (2006); Gliedt et al (2018)	SLBs are exclusively assigned to individual actors that inform institutions of required policy adjustments, as per Northdurfter and Hermans (2018)
Innovation intermediaries (e.g. policy entrepreneurs) work in environments of **institutional uncertainty** as per Gliedt et al (2018).	SLBs work in environments of institutional certainty and stability as per Breit et al., (2017)
Innovation intermediaries[2] **resolve technological, regulatory, administrative, technical issues and business risks** as per Lester & Hart (2015).	SLBs are forced to apply discretion and judgement within their roles as per Hupe & Hill (2007). SLBs resolve administrative and technical issues that may divert from formal policies (i.e. incremental innovation) as per Gofen (2014), Lipsky (2010), Seva & Jagers (2013) and Maynard-Moody et al (1990).
Actors that are **facilitators of knowledge** and mediators as per Bush et al., (2017).	SLBs represent a direct interface, mediators and facilitators of knowledge between the bureaucracy (i.e. regime level) and citizens as per Lipsky (2010), Hupe & Hill (2007), Gofen (2014), Lipsky (2010), Seva & Jagers (2013), Breit et al., (2017), and Maynard-Moody et al (1990).
May be individual **actors**, **interacting between the niche and regime level** as per Gliedt et al	Actors employed within the regime level or established bureaucracy that interact with citizens to

(2018) and 'middle-men' of technology diffusion and technology transfer as per Howells (2006)	diffuse knowledge as per Lipsky (1969, 2010), Gofen (2014) and Breit et al., (2017).

[1] Where this study argues that *success in wide-scale implementation* is likened to a heightened probability for *transition success*, whereby a transition is a series of implementable activities

[2] This paper argues that innovation intermediaries are radically innovative compared to SLBs.

Table 6.1. Summary of key characteristics of innovation intermediaries and SLBs in the scholarship

6.2.3 Bringing together ideas from policy and STS scholarship on intermediaries and SLBs

Both SLBs and intermediaries are theorised as central to successful policy implementation. Socio-technical scholarship has established that when a system transitions; competencies, skills and roles also begin to be re-fashioned (Geels, 2004). In terms of system evolution, a post-disruption phase is equivalent to a system maturing, and with this maturing phase, new roles and competencies would also stabilise; and this process could be supported by policy.

SLBs are essential for successful policy implementation, as are installer intermediaries, in transitioning electricity grids. However, a key difference between the roles of SLBs and installer intermediaries is 'environmental', where the *established* system is transitioning to an *emergent* system (i.e. transitioning from a centralised to hybridised grid). SLBs typically implement within established systems, while innovation intermediaries implement within emergent systems. Comparing the strands of scholarship, intermediaries can be described as radical innovators compared to SLBs as incremental innovators within a system. However, only once the structural transition has stabilised will installer intermediaries be able to undertake more of a classic SLB role. As the socio-technical system matures, so does the supporting regulatory framework, which then provides the stabilising operating environment that is more typical for SLBs. The rationale is that, there is less need for radical innovation from installer intermediaries post-transition, though there is greater need for competent installer operation in the context of more systematic processes that become the 'new normal', with a more traditional SLB implementing role played by installers. To clarify with respect to STS theory, the concept of energy system transition that is focused on in this paper is specifically referring to the potential of residential battery systems transitioning from niche to mainstream (regime) adoption.

The below diagram, Figure 6.1, describes the role change from intermediary to SLB over time. It explains that as the system matures, (i.e. post-disruption) regulations and policies are established. It illustrates that, while the electricity systems face challenges due to rapid structural transformation, *the risk is higher* for innovative niche development. New entrants, entrepreneurs and innovation intermediaries are required during times of transformation, while institutional instability is still so high. However, as the system matures and regulatory and policy frameworks emerge to support niche scale technologies and systems and to upscale them, the requirement for SLBs will be higher than for innovation intermediaries. It is expected that as the system matures (or stabilises), so too does the installer within the system, so that even within an unstable operational environment there may be some intermediaries transitioning into mature SLBs more quickly than others. This new normalised system facilitates a standardising of procedures, and maintenance of quality control.

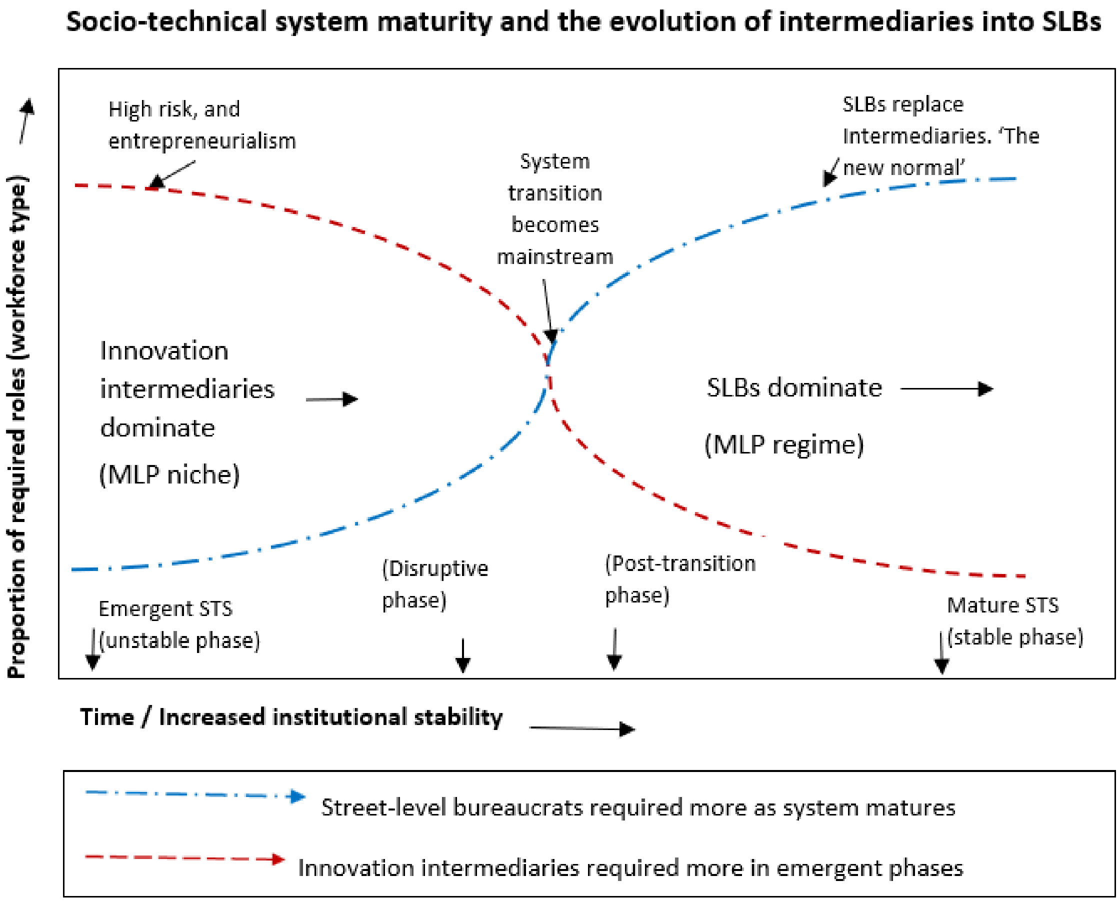


Figure 6.1. STS maturity and the evolution of intermediary roles into SLBs

In terms of systems theory and innovation intermediary evolution; the argument put forth in this paper is about institutional stability following a socio-technical transition. Specifically, the role of intermediaries within transition, and how roles and develop as the socio-technical system transitions. When analysing the transition of institutional instability towards stability, the institutional aspects of transition implicates governance and policy. The intermediary actors are within a policy and governance framework, facing "institutional uncertainty and instability" (Gliedt et al., 2018, p.1247). Institutional stability implies an orderly governance compared to instability and this is explored theoretically. The governance context of innovation intermediaries is institutional *instability*; however, it is argued that this transitions to institutional *stability* where SLBs become dominant.

Figure 6.1 above illustrates a post-disruption role transition for STS intermediaries. This stabilisation is a shift in the role from innovator (trouble-shooter) to a redefined skill-set and competence. The concept of system transition, or where the 'system transition becomes mainstream'. In the context of the electricity sector this would be when smart-battery installers are commonplace, represented with the regime. The intermediary-type roles diminish throughout the transition, and SLBs, conversely, increase as a proportion of the workforce and are typically incrementally innovative (adaptive) within the new, more stable framework.

Next in Section 6.3, the case study and methods are outlined as well as the contingencies facing the installers, as innovation intermediaries and potential SLBs in facilitating a socio-technical system transition in a somewhat orderly manner.

6.3. Case study background and methods

The introduction presented the CONSORT smart grid pilot project as a 34-household Virtual Power Plant (see Figure 6.2 below), and as an experiment of a possible energy future for a hybridised electricity grid. The household systems comprise solar PV and 'smart' internet-enabled batteries which trade electricity with the network. Householders are financially recompensed for the use of their battery by the network for supporting the grid. Whilst the aim of CONSORT was to test out a more cost-effective solution for reliability and to defer infrastructure upgrades, the project can also be viewed as an opportunity to test a future grid in which householders play a greater role.

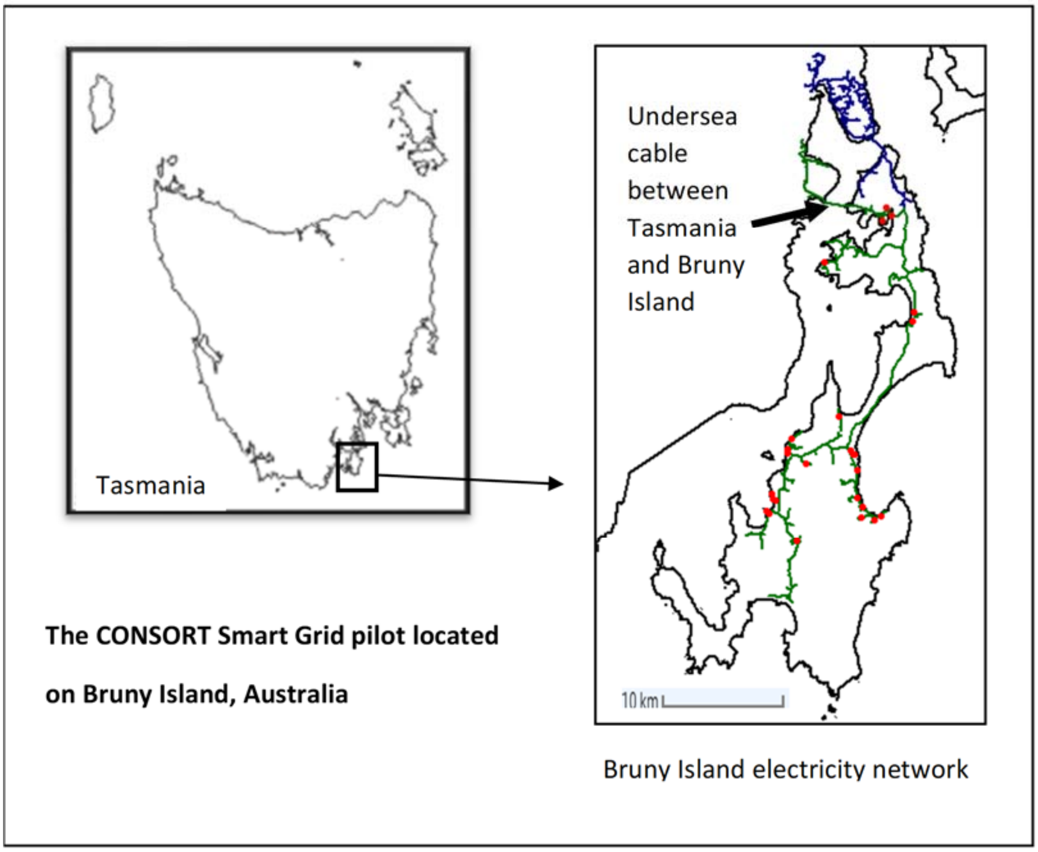


Figure 6.2. The site of the smart grid on the small island of Bruny Island off the coast of Tasmania, Australia

As far as the project is concerned, the installer's primary role was to safely install the equipment, designed to the householder's requirements and to explain the system to the customer. The installer role was technical, and facilitative between the network utility (regime) and the energy prosumer (where a prosumer is an 'evolved' energy consumer that both produces and consumes energy (Kotilainen, 2018)). Installers specific tasks were to install the solar PV panels, inverter and battery, and to commission the smart-battery software that is provided through Reposit Power. Reposit provided an internet-based, battery management system to prosumers; but this first must be 'commissioned' by establishing an internet connection between the battery and Reposit so that Reposit could monitor and control the battery remotely. The housing for the battery was also fitted; the safety and function of the system needed to be communicated to the householder; and the installers were expected to establish with the householder which circuit they wish to use as back up in the case of an outage.

The installers were assessed through a tender process that was managed by TasNetworks. Installers that were deemed compliant in meeting project requirements were selected as a group of six that the participants could choose from. The installers were observed as key intermediaries for the successful implementation of the project as they were the interface between householders and the network and were knowledge brokers. They were generally trusted, as SLBs typically are. They were commonly the first person or organisation householders contacted if something went wrong. They explained how the system worked and could either solve problems or increase frustrations. In terms of the CONSORT project, their role expanded to having to liaise between the householder, TasNetworks, Reposit, to install the system, and they were also required to liaise with manufacturers of batteries, inverters and solar panels. This additional liaison was pivotal to implementation success.

Thus, the installers negotiated a number of relationships within the project as described above, and as depicted graphically in Figure 6.3, while the CONSORT customer engagement and trial deployment is represented by Figure 6.4 (both below).

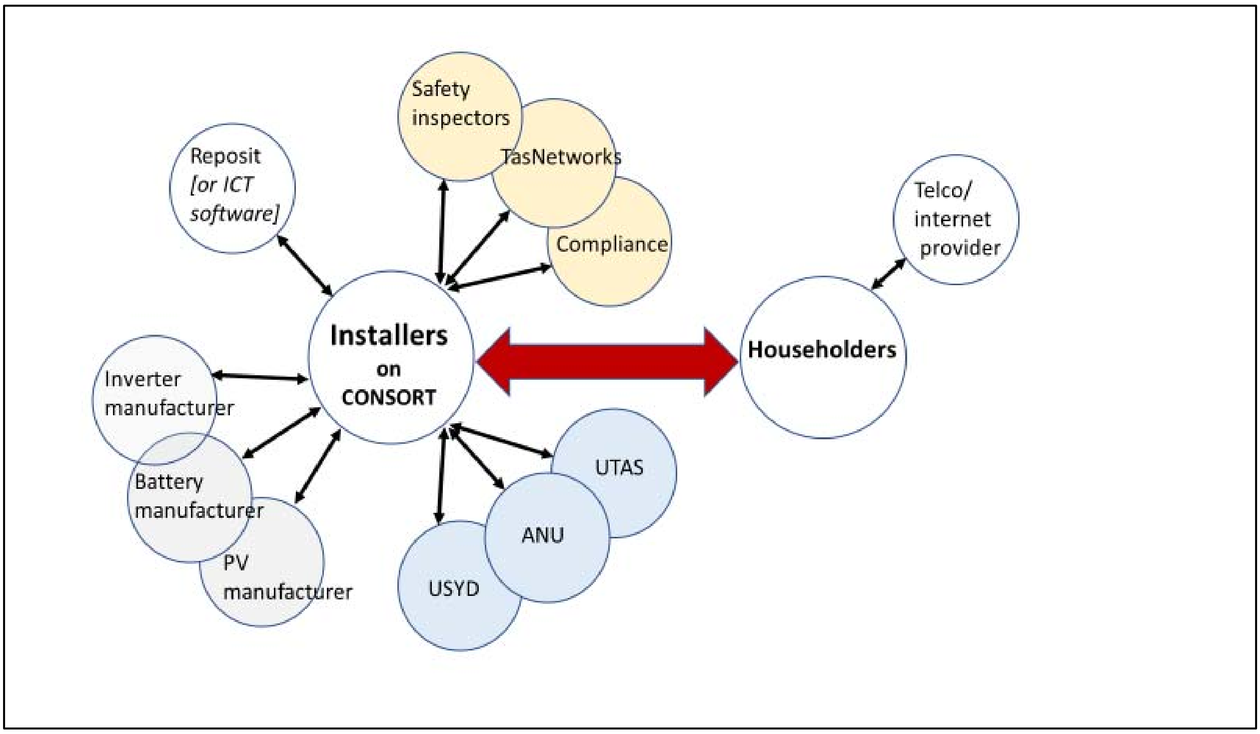


Figure 6.3. Relationships that the installers on CONSORT managed on behalf of the household participants

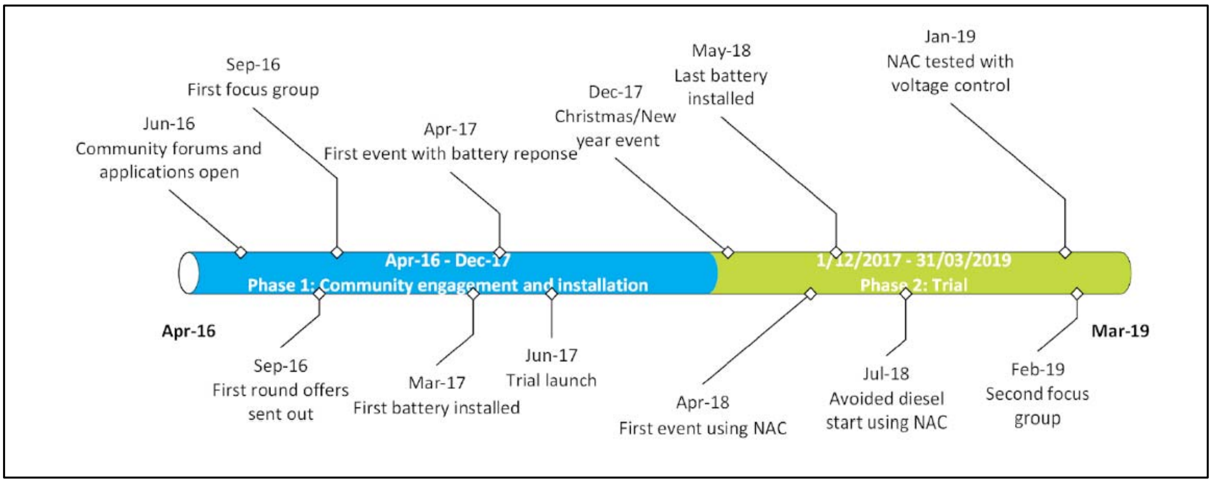


Figure 6.4. Timeline of project with Phase 1 as Community Engagement and installation. from Project Final Report Lessons Learnt During Trial Deployment, (Jones et al., 2019 p.12)

This research was part of a wider suite of economic, ICT, and electrical engineering research within the CONSORT smart grid project (H. Lovell, Hann, & Watson, 2018). The approach of the present study was a qualitative inductive approach to the roll-out of the project and householder responses. Evidence was drawn from a 3-year longitudinal investigation of 34-householders that were asked about the installers as part of the interviews. The householder interviewees were recruited by the utility (TasNetworks). The householder interviews were conducted at the home of the householder after the installation of the PV-battery system, with structured and semi-structured questions, audio recorded and transcribed, in the period July 2017 – Jan 2018. Six installer firms were contracted by the TasNetworks (project partner) to implement the installations. All six firms' general managers were contacted for interview by the lead author. Three of the six agreed to interview. The three installer interviews were conducted between Nov 2017 – Dec 2017. The general managers were also installers themselves and the businesses were small to medium sized Tasmanian businesses. In terms of the project participant demographics on Bruny Island, the cohort were over-represented in the over-60 years age bracket and could be described in general as non-early adopters. This particular demographic might be helpful to conceptualise how this might relate to mainstreaming/upscaling of smart batteries to the regime given the cohort were non early adopters.

CONSORT project partners were also interviewed for this paper about key learnings related to installers and the installation process during the project. These interviews comprised one innovation engineer from the utility and two ICT experts from the new entrant project partner, and these interviews were conducted between Oct 2017 and Feb 2018. Finally, two battery system installers were accompanied, or shadowed for a day on site to Bruny Island on one of their installation jobs in April 2018. The interviews were audio recorded and thematically analysed.

The following section describes how the installers were positioned as catalytic intermediaries between the utility and consumers (households), and as critical in successful policy implementation, and hence why we view them as policy SLBs. Missing from both government vision and the literature on STS intermediaries is a consideration of the 'scaling up' role of installers. The concept of *scaling-up* is of interest to the CONSORT project, because the project is a small-scale demonstration of a new system that could potentially, indeed, is expected to, have wider applicability, in terms of the deployment of smart technologies in other jurisdictions. The CONSORT pilot aspiration is for a mutually beneficial situation that balances the economics, network requirements and householder requirements.

6.4. Empirical analysis: the role of installers on Bruny Island

The empirical findings comprise qualitative data from interviewees on the themes as outlined below. Key findings are discussed in detail in relation to the policy implementation gap as follows: the pace of technological change; and the importance of education, engagement and learning. For this case, learning includes intentional learning and unintentional learning as it relates to the installer firms.

6.4.1 The implementation gap — Complexity, policy, and pace of technological change

The pace of technological change compounds the complexity faced by installers in their day-to-day operations. However, at a high level, it is argued that there is a mismatch between technological innovation and policy innovation that may create significant, unintended consequences. For example, one installer warned of the current risks of ad-hoc, ill-thought out policies to accelerate implementation. The installer perceived dangers from a governance perspective; as observed from previous Australian government policy implementation failures. The installer compared the 'early days of solar' to the current deployment of batteries, and that 'worldwide you are going to see a lot more integration of energy storage in household systems.' However, his concern about the management of an accelerated transition was the unintended consequences and risks of incentivizing industry 'cowboys' —

> 'whenever you have a rebate of some sort of subsidy, it does encourage…a quick take up of batteries…but it also encourages…cowboys too; and people to come in and take advantage of that rebate. And, I guess what the [Australian] pink batt scheme and the solar schemes in the past…have

illustrated is that people come in and take advantage of it, and potentially government won't get the solution they're after…the end user might lose out.'

(Installer interview A, Nov 2017)

The installers acknowledged the acceleration of *technological* change, emphasising how from their perspective that change 'on the ground' is outpacing shifts in the policy and regulatory environment, for example —

> 'In the last 3 years we've seen the [battery] technology basically develop from nothing, into something that's suitable for the residential home…It's a learning curve for everybody, the networks have a massive problem on their hands — because — they've got all these technologies that are going faster than they can keep up with'

(Installer interview B, Dec 2017)

The installer quoted above describes a classic innovation intermediary situation: an uncertain institutional environment; high learning and high risk with little policy support during a time of transition. This environment is described in Figure 1 on the left-hand side of the diagram — where more high-risk innovation intermediaries exist (than SLB types) within low institutional stability in the emergent, or transition phase, of sector change.

One of the utility engineers working most closely on the project also described the high risk faced by the installers in terms of the pace of change ---

> 'It's an issue with this transition with two new technologies and new ways of working…it's hard for the installers that don't necessarily have a lot of capacity…the Reposit system has more moving parts…extra things they need to connect up and make sure it works, and sometimes it doesn't '

(Utility engineer, Feb 2018)

The complexity and the pace of technological change facing installers has been described, with the installers, managers of installation companies, and the engineer of the project in agreement that the complexity level is high, the technology change is rapid, that integration is an issue, that the impact of ill-designed policy support is considered negative, and that the learning rates of the installers and other actors within the energy system is steep. Next, education and engagement are examined as potentially greater threats to effective implementation than complexity and pace of change outlined above.

6.4.2 The implementation gap — Education and engagement

6.4.2.1 The level of householder engagement

The high level of engagement and support required by householders on the CONSORT project was unexpected and involved extra resources from our industry partners than originally planned. Further, in some households a great deal of this engagement and support was provided by the installer. Households were asked in post-install interviews about who they would contact for technical support, if they were experiencing problems and 81% said they would contact their installer. Even so, there were a range participant responses depending on how reliable the communication was from the installer. Some participants reported a break-down in communication with the installer, where the most extreme case was an installer contractor that was unresponsive over a period of time and did not complete the commissioning of his assigned systems. This issue was traced back to one installer firm that exited the CONSORT project without completing the contracted work. The installer impacted 12 of the participants, and the network utility project partner was required to intervene and complete the installations and commissioning of the systems.

The responses from householders ranged from frustration and lack of engagement, to being supportive of the installers, but frustrated by the process itself, while others were impressed at the amount of effort and investment of time that was provided by the installers and were content with the level engagement and knowledge: Overall, **the householders recognise that it is hard work for the installers.** From the installer's viewpoint, there were also some insightful observations made by installers with a systemic understanding of their situation, and the complexity and education required. The impact of the significant level of engagement undertaken by the installers was an unexpected finding, and it was considered a core priority by the installers and more difficult than the technical issues by comparison. Observations are evidenced in Table 6.2.

Interviewee type/date	**Theme — evidence of reliance on installers and risk to installers**
Installer A, Nov 2017	'This issue…everything comes back to the installer. And, even if it was a different supplier, people don't understand...they won't go back to the supplier…it always goes back to the installer…[if] the installer's only around to install it and nothing else, who's looking after it when something goes wrong?…. If they deal with a company that deals with the whole thing, that offers that education…the ground service; well that comes at a cost, because your business is going to be there

	standing the test of time…but there's a cost associated with that, and people don't understand that.'
Installer B, Dec 2017	'[My] main challenge is educating people on a day to day basis about this new technology…that's the biggest challenge full stop. Installing the equipment is easy…It's not like selling a TV…you are selling a complete customised solution for a home and it involves a lot of different factors, and everyone has different needs and different requirements and that all needs to be carefully talked through, and for you to be able to provide that tailored solution that they need… Now – for them to be able to realise the value in that, they need to be educated.'
Utility engineer, Oct 2017	'The [installer firm name] saga — I can't get hold of [installer name], and if he loses his customers, it sort of implies he's stopped trading. A lot of the installers are on a knife edge. So, having something that is an unexpected cost – can — sometimes…be betting the business on it.'
Utility engineer, Feb 2018	'For trial it's okay, but…if [utility name] has, say 10,000 customers with batteries, we can't offer 'Bruny level service' to everyone. In the end…it needs to be provided by 'someone' – and, in reality – it's either going to be people like [ICT name] or the installers'
Householder, BT106, Oct 2017	'I think the person that I chose as the installer actually ended up overwhelmed with the volume that he had, and didn't time-manage, and his communication was very poor…There were also problems with some of the software. It was confusing, but I think the thing that was most disappointing was the person that I chose as the installer.'
Householder, BT120, Jan 2018	Q: Who is the first person that you'd call or email? A: Well, [husband's name] would ring [installer's name]. I presume, because he's responsible for the battery, isn't he?
Householder, BT121, Jul 2017	Q: Who were your most trusted sources of advice on this technology? A: Well, as you said, I've certainly been in contact with the installer who's been very, very good and very quick, as I mentioned before, to help out'
Householder, BT110, Dec 2017	Q: 'And have you needed to contact anyone for technical support? A1: No. Q: No, okay. And if you did, if there was some issue with the technology, who would you contact?

	A1: Just [installer's name]'
Householder, BT125, Nov 2017	'It went absolutely wonderful because the whole system rolled up on the job with all the experts in every field…I let them do their stuff during the day and basically every five minutes I'd just drop in and see how things are going and they gave me instructions on how the whole thing's done, and I was really, really impressed.'
Householder, BT126, Jan 2018	'To be frank, we got very hot and bothered…[The installer had to come back a number of times but]…He didn't quibble at all. He's carried a lot. And never a feeling that we've been inconvenient customers. You can tell he's frustrated, and additional costs.'
Householder, BT108, Jun 2017	The 'installer spent close to 40 hours post-installation helping.'
Householder, BT115, Nov 2017	'I think, logistically, for the installers, bit of a nightmare because the ferry and the timing and the cost is so limiting. I mean, they must charge them a fortune...'

Table 6.2. Risk and reliance on installers

Expressed above are a range of themes related to the engagement and education functions being required of the installer. They are trusted, as SLBs are, but are working in an innovative and less stable environment than SLBs, where every onsite-job may present quite unexpected problems. The time it takes to navigate this environment because of the newness of the role and the sector, and the complexity involved. These factors pose a risk to installers and, without a routinized environment, to the installation process. These risks are linked with learning and are illustrated further, below.

6.4.2.2. The implementation gap — Installer learning and risk

The installers were appreciated for 'going above and beyond' the installation process by householders, and the installers certainly see education as central to effective implementation. The installers often expressed that their whole role is 'education' – whereby *'installing is the easy bit.'* Partly this stems from system complexity and the process of educating householders, that result in the systems with very customised solutions. For example, the installers ask the customer to choose what circuit is important to them for the emergency power supply (EPS) backup in the event of a power outage, e.g. the computer —or water pump, or freezer, which are on different circuits. Where the installers have a strong knowledge base, not just of products, but of how the systems integrate, and spend more time at the planning stages, it makes a significant difference for implementation success. For example, some installers pre-fabricated the cabinets (battery housing) and ensured everything fitted and was operational before arriving to site. However, only two installers out of six did this pre-fabrication and pre-testing. For less resourced installers this meant 'the road to hell is paved with good intentions' meaning that despite the best intentions, as the TasNetworks engineer noted – 'sometimes it made it [the installation process] worse.'

Occasionally, installers were found to not have a strong knowledge of some products, as well as having issues with technical integration. With these knowledge gaps, they sometimes introduced measures that counteracted the Reposit software; causing system failure and economic and technical losses or wastage. This 'reverse engineering' or 'tricking up the system' whereby installers, without full knowledge of the system would try to alter it to suit the customer led to the unintended consequences of technical and economic loss, frustration and installations that initially failed to operate. For example, instead of using one circuit as back up, they might provide two or three, meaning that less energy would be available for the network, contrary to the trial objectives. Another example is changing the 'depth of discharge' of the battery and setting it too high – so that little is left for the network – which might be good for one individual, but not for the network. The objective of the software design is to sell when the cost of electricity is high, and to store electricity when it is low, thus coordinating with the network tariffs to benefit the householder economically. However — what was discovered in some situations was that the software and tariff structures were providing contradictory instructions, which was not aligned with the project objectives or householder benefit. Frustrated customers with partially working systems was observed, and a possible outcome could be a financially disadvantage, increased stress, and a lower likelihood of acceptance of the new technology. For example, the assessment of the TasNetworks innovation engineer working most closely with the pilot was that the —

> 'installers are playing around with the settings just trying to get a good outcome but made it worse! ... they went the extra mile but often made it worse.'
>
> **(Network utility engineer, Oct 2017)**

Complexity, and the inefficiencies of learning, were risks, as evidenced in Table 6.3 below.

Interviewee type/date	**Theme — Installer challenges, learning, complexity and risk**
Householder, BT128, Jan 2018	‘Ongoing confusion. With all aspects, to be honest…At another level, with respect to how it integrated with the household electrical system, once again there was no planning in advance of that, and there were some critical questions which evolved…on both occasions that he came, and pointed out to me that there were many implications for how our system operated, and with respect to what circuits should be on it and what type of equipment should be – what modifications could be included in the equipment itself to account for which circuits were connected to the battery, and which ones weren’t.'
TasNetworks engineer, Feb 2018	‘All the installers were relatively small [firms]. The time pressure to move onto other jobs, and to tail off engagement was high. For the installers as small businesses, it was make-or-break, margins were narrow, and investing in learning for future innovation was a large financial risk in itself, where a satisfactory installation process was “life and death”.’
TasNetworks engineer, Feb 2018	‘Reposit is meant to be set and forget…It’s like reverse engineering, but sometimes you get outcomes you weren’t expecting when you do that.’
Installer B, Dec 2017	‘It’s a learning curve for everyone…but how it gets deployed is complicated. At the moment, plenty going on [in the industry], batteries are going down in price- and it allows the industry to get sorted properly, to get decent installers in the industry. Demand will increase--- steadily increase – but big subsidies [create] a big mess. It’s best to rollout at a manageable pace—it keeps quality up; keeps people honest; better result. ‘
Installer A, Nov 2017	‘We knew we wouldn’t make any money on this pilot, we saw it as learning for the future and we need to skill up our guys and gals up and refine our product offering.’

Table 6.3. Installer learning and risk— addressing the implementation gap

In summary, it was found that installers grappled with the pace of technological change, in particular where it came to integrating components including new software; however, perhaps surprisingly, the education and engagement aspect was considered even more vital by householders and installers than the technological considerations. The investment of time, trouble-shooting and tailoring, and engagement was key, and the installers were the primary ‘first port of call.’ What was seen at a higher level was the unexpected, negative effect of ‘going above and beyond’ in an unregulated environment; where a steep learning curve prevails. The learning was useful to the installers but also represented a risky investment for small businesses.

The importance of education and engagement is highlighted, and the impact is arguably greater than it is for the technical issues of complexity and rate of change; partly because adoption (implementation) depends on the most detailed level of policy implementation, the point of interaction of the householders and the installers.

The next section highlights the installer characteristics that were SLB-like, in that either the installer new-system competencies, or that the environment supported SLB-evolution through education and knowledge sharing.

6.4.3. Closing the implementation gap

The case study found that the installers (as innovation intermediaries), were similar to SLBs for the *best practice* installers. In summary, the similarities between installer innovation intermediaries and SLBs are that both types of actor are trusted and expected to provide knowledge; they work with citizens every day; citizens are impacted by them; and they influence policy outcomes by shaping it at the coal-face of implementation. However, the differences are significant: The SLBs (unlike innovation intermediaries) are not forced to cope with constantly changing conditions but have routinised work that they are competent with. SLB characteristics shown by installers included: The installers who pre-fabricated the cabinets (battery housing), checked and tested the software integration before they went to site, and put additional initial effort into improving their processes for their technicians. Taken together, these can be described as creating SLB environments. SLBs have more routinised tasks in a more settled, less unknown environment, and this should predispose a future role for best practice installers.

6.5. Discussion and conclusions

This paper explored the concepts of intermediaries and SLBs in system transformation, innovation and implementation success. The case study provided observations of intermediary installers grappling with a steep learning curve and limited resources. This is in contrast, and unlike stable SLB counterparts — installer intermediaries have little policy and governmental support. In the case study the SLBs were the ‘advanced’ installers, and this appeared to be due to the improved business practices of the firm they worked for. Intermediary roles can transform into SLBs, (advanced/competent installers) even in times of institutional instability; the roles can be enhanced to increase competencies and learnings, and we argue this could be achieved through targeted knowledge sharing, training and provision of policy and regulatory support.

The original contribution in this paper is the theory of the role development in STS emergent systems to 'post-disruption' stabilised systems as illustrated in Figure 6.1.

In brief, with reference to Figure 6.1:

- Intermediaries should evolve into SLBs as system matures and new industry competencies are commonplace.
- The change in roles from intermediary to SLB extrapolates to a 'new normal' and post-disruption for roles with new-system competencies; (for example, with standard operating procedures, improved communications and training).
- Installers demonstrated significant influence and impact for acceptance for Bruny Island case study, and best-practice, 'advanced' installers we view as 'emergent SLBs', and,
- Innovation intermediaries role transition could be accelerated with policy support.

Innovation intermediaries are considered to be pre-cursors to SLBs due to the relative institutional stability, the relative level of risk, the relative level of innovation versus bedded-down competency, and relative policy support and training – it is suggested that innovation intermediaries are on a continuum of (a non-linear, staggered) evolution and transition over time

The argument presented is focused on a small aspect of transition, whereby SLB theory offers a projection of a possible future. Applying SLB theory a plausible prediction of a future scenario is estimated; because under a stable environment installers (intermediaries) are observed to have SLB-like characteristics. This paper sought to understand the evolution of innovation intermediaries *post-disruption*; once a socio-technical system stabilises and matures. It was found that SLBs reflect stable institutional environments and bedded down competencies. The best-practice installers in our case study represent a future view that incorporates 'orderly governance' and the conversion of these installers as intermediaries into SLBs.

A novel contribution of this paper in is applying the SLB policy implementation scholarship on a contemporary case and projecting this into the future, rather than applying retrospective historical analyses.

In conclusion, installers are observed to be pivotal to residential battery storage implementation, and the case study indicated that, for the installers, the non-technical issues of customer engagement and education were a more significant barrier to implementation than the technical issues of ICT systems integration. The case found that some intermediaries were best practice and SLB-like with new-system competencies. The SLB-like installers effectively responded to the increasing technical complexity, in their own transition from solar PV technicians to IoT (smart battery) installers. This paper described how innovative intermediaries evolve post-disruption once a system stabilises and matures. With respect to orderly governance and policy implementation; the installers role is expected to evolve from intermediary to SLB. Our case study positions the best-practice installers as emergent SLBs; and the current systemic risk is recognised that battery system installers face with their roles increasing in complexity; from PV technicians to IoT (smart battery) technicians.

Policy learning from this case study may lead to additional, targeted policy support for the installers to assist in translating their roles to stable SLBs post-disruption. This would, in theory, assist in closing the implementation gap within a residential system transition to greater decentralised storage. This paper presents for a conceptualisation of installers as novel SLBs; where this role provides possible future insights into the linkages between technology, innovation and overcoming policy implementation barriers.

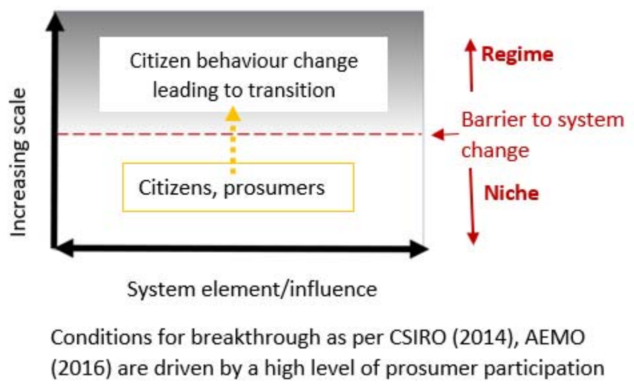
A contextual lens and outline for the paper ahead, Chapter Seven

This outline introduces the paper 'Transition to decentralised storage: Consumer decision-making and cost benefit analyses' that is in the place of Chapter Seven, which was been submitted for review to the *Journal of Energy Policy.*

The empirical material that this paper drew upon included data provided by TasNetworks, pricing and other financial data provided by participant BT112, interviews with BT112 and other householder participants, and interviews with two grid economists and two power systems engineers.

This paper contributes to the thesis an understanding of aspects of proto-prosumer decision making and aspects of decision making that fall within a cost-benefit analysis (CBA), investigating whether battery systems are cost-effective for households. Additionally, the paper identifies important intangible issues related to decision-making that do not currently fall within the remit of a CBA.

The paper centres on concept of 'consumers at the heart of the energy system', examining the potential to drive transition through consumer preferences. Schematic C below illustrates the consumer-centricity of transition that is the focus of this paper and is a key element of the theoretical basis of this thesis. The niche-regime boundary is equally considered to be an implementation gap in terms of accelerating innovative breakthrough to the mainstream.



Driven by Prosumers as a condition for innovative breakthrough, Schematic C

In summary, the focus of this paper is on potential prosumer decision-making as key to transition. Hence, this paper may be viewed theoretically through the lens of citizens driving change, as a key determinant affecting the rate of socio-technical systems transition.

Chapter Seven

Transition to decentralised storage:

Consumer decision-making and cost benefit analyses

Abstract

An industry supported pilot on Bruny Island, Australia (2016-2019) trialled household smart-battery deployment — to support the local network in times of peak demand; whilst also recognising more widely that harnessing storage is a key to an orderly electricity transition. This paper focuses on consumer decision-making as key to a transition towards decentralisation and conducts a cost benefit analysis (CBA) on a participant householder.

Findings include: applying a CBA found that without a subsidy, the battery system is not yet cost-effective, and that while cost is an important factor, other non-financial factors are influential, including battery backup, not captured by a CBA. The CBA-assumptions reveal the complexity and uncertainty behind a seemingly transparent methodology. This research addresses a scholarly gap, whereby, despite the common use of CBAs within industry, significant householder values and assumptions are not captured.

Policy learnings include that consumer decision-making about purchasing batteries is influenced by non-economic values and that CBA analyses may not be a good predictor of a system transition to distributed storage. Finally, to encourage battery uptake, providing differential incentives between edge-of-grid areas compared to urban areas may assist equity in electricity reliability for rural consumers.

Keywords: Cost-benefit analyses; Residential battery systems; Prosumers; Smart grid; Energy market politics; Decision-making.

7.1 Introduction

The conditions for a paradigm-shift more decentralised storage appear poised for a mainstream transition; and according to observers, the era of affordable small-scale renewable resources has arrived (Blakers, Lu, & Stocks, 2017; Leitch, 2019; Reh, 2017, p. 330; Winter, 2017**).** Additionally, there appears to be a consensus between policymakers and business actors encouraging battery deployment, particularly in the state governments of Australia (ACT Government, 2019; Government of South Australia, 2019; Queensland Government, 2018a), and, where this occurs, rapid acceleration of socio-technical transitions is expected (Roberts & Geels, 2019, p. 1081). Enhancing the trend towards a wide-scale energy transition are high levels of solar PV; economically accessible lithium batteries (Bellini, 2017), (Nykvist & Nilsson, 2015 p.6) (IEA, 2018); rising electricity costs (Truong, Naumman et al. 2016, p.1; Wood and Blowers, 2017a, p.8-16) and support by governments for storage (ACOLA, 2017; Mazengarb, 2019). Half of all Australian homes expected to take up battery storage systems on the basis of cost, at an apparent tipping point of $10,000 and a 10-year payback (Stockers et al, Clean Energy Council 2015, p.ii). This paper refers to relevant CBA online interactive tools, and an industry CBA example, and then undertakes a CBA from the point of view of the householder. That is, the costs and benefits that are relevant to consumer decision-making, and not an analysis of the CONSORT project, or project partners such as TasNetworks. So, this chapter takes a different perspective in applying a CBA, as it does not consider the network perspective or the cost of reducing emissions and so forth. The household-specific CBA also incorporates discussion of other non-financial values in order to address the gap of the consumer perspective within the electricity sector transition. To emphasise the significance of this point, the CBA approach of this chapter is attempted for the following reason: consumers are the final deciders in whether to adopt smart battery systems, the smart battery systems operate at the residential-level and depend on consumers adopting them, not networks, therefore, the consumer perspective is argued as being of direct relevance in the system transition.

Ultimately however, this transition hinges upon consumer preferences and decision-making because the transition depends on consumers investing their own money into distributed storage resources and the network subsequently not having to replicate this resource at tax-payers expense or at a network and utility expense, but to procure these batteries for network support services. Householders are therefore recognised as central to transition (ARENA, 2019a). However, a key challenge for the networks, governments and energy market operators better understanding how to work with, incentivise and manage this consumer-centric transition.

This paper centres on the concept of problem typologies (logics) in relation to consumer-decision-making as a key driver towards a sustainable transition. Specifically, the decision-making typology investigated is the cost-benefit analysis methodology. This study is the result of a three-and-a-half-year industry-funded social science doctoral study, which was part of a social science team and larger smart grid pilot, CONSORT (CONsumers providing cost-effective grid suppORT) (2016-2019) funded by the *Australian Renewable Energy Agency* and was carried out by three Australian universities, an incumbent transmission utility and a software (ICT) new entrant. CONSORT is a test for future smart-battery deployment, conducted on Bruny Island, Australia, and with learnings expected to be applicable more widely. The pilot sought to assess the cost-effectiveness of smart-battery systems for the network and consumers.

This paper investigates a participant householder in detail within the CONSORT smart grid pilot and applies a householder-centric cost-benefit analysis (CBA) as a decision-making method, detailing the underlying assumptions. This approach attempts to address a scholarly gap, where there is no scholarship at the time of writing that analyses CBAs and battery storage from the householder perspective. This is significant as householder decision-making is considered central in transitions. In addition, in focusing on the CBA methodology itself, most of the social science scholarly attention is directed on inherent flaws in the CBA methodology, and not the critical importance of context of CBA application. This paper acknowledges and examines both the most critical weaknesses of the CBA methodology — and its suitability when applied appropriately.

The paper is structured as follows: the section below (7.2) describes the CBA methodology, examines the application of CBA in the solar and storage industry as applied to householders, provides a critical analysis of the CBA methodology from a sociological perspective, followed by the rationale of where the CBA fits within typologies of problem structures for decision-making. The methodology and approach are described in Section 7.3; the case study findings in Section 7.4; discussion in Section 7.5; and conclusions and policy recommendations in Section 7.6. The Appendix lists the assumptions underpinning the CBA.

7.2 Theoretical framing and literature review

CBA is a common method used for decision-making and has been applied and discussed in relation to battery systems (residential and business) by academics, industry commentators, government departments, energy utilities, energy journalists, battery manufacturers and others (Doyle & Barnes, 2016; Gilding, 2017; HBCSolar, 2018; Idlbi, von Appen, Kneiske, & Braun, 2016; Mateo, Reneses, Rodriguez-Calvo, Frías, & Sánchez, 2016; 2013; NSW Government, 2017; Parisot & Freund, 2017; Potter, 2017; Pratt, 2017). Advertising and marketing for residential batteries to consumers often includes simplified CBA-like, online interactive tools (EnergyMatters, 2016; SolarChoice, 2018).

However, a CBA is not commonly initiated by householders for decision-making on purchases, yet the wider assumptions of a rate of system transition seem to infer a householder-CBA logic, with cost as the driver for uptake of the technology (ARENA, 2019a; Brinsmead, Graham, Hayward, Ratnam, & Reedman, 2015; Leitch, 2017). However, a sociological analysis of CBA from the householder perspective in the solar and storage industry has to date not been undertaken. Given that consumers are central to transition, this is contended to be a research gap, and is addressed in this paper.

Next, the CBA methodology is outlined in Section 2.1, followed by an evaluation of decision-making typologies in Section 2.2, and where the CBA fits within this structure.

7.2.1. The CBA methodology and criticism

In 1844, engineer Jules Dupuit devised the concept of CBA as a way to capture social utility in public projects and is still held as 'one of the most influential papers in the history of economic thought' (Maneschi, 1996, p.411). The aim of Dupuit's method was grounded in pragmatism; it was to provide a quantitative evaluation of the value of a 'public good in order to choose the socially best quantity and financing of public works' (Kolm 1987 in Maneschi, 1996, p.413). The CBA method is systematic and simplifies decision-making for financial or technical types of problems. However, Dupuit's CBA method was controversial even among economists of the day (1996, p.413), and one reason was the concept of a Willingness To Pay (WTP) by consumers for an economic good. Dupuit conceded many years later — 'that a person's WTP for a good depends on his wealth, tastes, prices of substitute goods 'and a thousand other circumstances impossible to enumerate completely' (Dupuit 1933 [1849]:111)' (Maneschi, 1996, p.425). Despite this apparent conflict of logic, the CBA method was designed to consider equity, through the weighting of non-financial values by estimating these financially and justifying the assumptions.

A CBA evaluation is undertaken by firstly by converting all costs and benefits into a common currency. A discount rate is applied, and this converts the amounts to an estimated net present value (NVP), which provides an equal-footing for the time-value of money. From this, a cost-benefit ratio (CBR) can be calculated. Sometimes a sensitivity analysis is performed, which compares a weighting of those costs and benefits, also considering the effect of Net Present Value (NPV) and discount rates (Treasury, 2015; Commonwealth of Australia, 2006, p.xi; Plowman, 2014; Reh, 2017; and Keat et al, 2014).

CBA traditionally attracts its' most serious criticism from social science scholars. For example, that the CBA method does not 'produce morally relevant information… [and the defenders] form an increasingly beleaguered minority' (Adler & Posner, 1999, p.167). This assertion, two decades ago renders the CBA as a somewhat dangerous 'morally irrelevant' tool that is fading out of existence. Yet, by contrast, the methodology has also been criticised as being too powerful, where 'there is hardly an issue in government that is not framed by the logic of cost-benefit analysis'

(Espeland and Stevens, 1998, p.324). Despite this statement, CBA remains in widespread use in government and industry.

A key concern for social scientists and ethicists about CBA is the deceptively simple ingenuity and the danger that it systemises decision-making because it 'transforms qualities into quantities, difference into magnitude' (Espeland & Stevens, 1998, p.316). In a categorical sense, CBA equates apples and oranges, and the act of equating the incommensurable is vexing from an ethical perspective. Weighing non-fungible values is a subjective process and 'methods claiming objectivity, such as cost-benefit analysis, derives also from a sense that they often measure the wrong thing' (Porter, 1996, Ch8, p.216). Thus, the key problem here is the CBA 'tries to measure diverse social goods along the same metric' (Sunstein, 1994, p.841). CBA has also been described as 'a political response' (Espeland and Stevens, 1998, p314), as CBA forces choices about what to value and what to overlook, so it 'is not a neutral or merely technical process' (Espeland and Stevens, 1998, p.323).

The concept of politics is commonly connected with large, systemic issues; and an important example of the possible political influence of a CBA within the Australian electricity system is argued to be the Value of Customer Reliability (VCR). The VCR is estimated at a macro-scale and assesses the risk and assigned cost of electricity outages within the National Energy Market (NEM). The level a VCR is set at can drive or halt energy infrastructure development at a national scale, and hence it is politically very powerful. The 'VCR is a critical input into identifying efficient levels of network expenditure' (AER, 2018, p. 3), and 'VCRs are widely used in the NEM…as a key factor in assessing network's major capital projects and overall capital forecast' (AER, 2018, p. 4). On the macro-scale the VCR is a device for a series of NEM-wide CBAs. The way the VCR gathers data from individual consumers is through sample surveys. The *Australian Energy Regulator* suggests 'A possible downward driver on VCR would be storage solutions such as battery…solutions as these further decrease in cost and are taken up by a greater number of customers' (2018, p.5).

The deployment of residential batteries in relation to householder decision-making is similarly, dependent on 'political' values and issues — that is, the subtle but nonetheless powerful implications of assigning or disregarding particular values within a tool as a householder-scale CBA. A CBA includes or disregards issues and values, and this happens at the macro-scale (e.g. large infrastructure projects), and critically, also at the micro-scale (e.g. individual-level decisions). Thus, the presentation of a CBA as neutral and objective needs to be questioned, and this is demonstrated below in a detailed examination of the underlying CBA assumptions, including the choice of a discount rate, in the householder CBA case study (see Section 7.4).

7.2.2. The application of CBA within the solar and battery industry

In terms of battery technology and decision-making, a large quantitative study by *Energy Consumers Australia* concluded that '[householder] Judgments on solar electricity centre almost entirely on cost. The most important reasons for installing solar electricity systems are wanting to reduce energy bills and wanting to reduce dependency on mains electricity' (UMR, 2016, p.4), and a key concept of the CBA method centres on the 'willingness to pay' (Commonwealth of Australia, 2006, p.xii).

Some firms have online CBA calculators for consumers to assist decision-making (EnergyMatters, 2016; SolarChoice, 2018), on the basis that economics is the central driver for householder decision-making. An example of a simplified CBA by HBCSolar for a solar system (simpler than for solar plus batteries) for a family of four in a region of good solar insolation (Newcastle, NSW), outlines the financial benefits as an annual bill cost saving, as presented below in Table 7.1.

HBCSolar CBA specifications and marketing	
System size 3.24 kW PV	Estimated lifespan 25 years
Estimated self-consumption 70%	Estimated export 30%
Buy from the grid at 28c/kWh	Sell to the grid at 5c/kWh
Yearly benefit = [self-consumption (70% expressed as 3311kWh) x 28c/kWh] + [the amount exported (30% expressed as 1419kWh) x 5c/kWh] = $1000 saved per year (HBCSolar, 2018)	
Listed HCBSolar assumptions: no shade and good solar insolation, north facing panels, the estimated export/self-consumption,feed-in-tariffs (as above), and an estimate of electricity use reduction by 79%.	

Table 7.1. Data from 2018 solar PV CBA (HBCSolar, 2018)

Similarly, in an *Energex* battery trials report, a cost-benefit logic is set out for residential PV-battery systems (Energex, 2017a, p.19). This report illustrates a positive benefit-to-cost ratio (BCR) where six factors are favourable, namely, the conditions of a 1) a large household, 2) high annual consumption, 3) high evening consumption, 4) large PV systems, 5) generous solar feed-in-tariffs, and 6) consumption that can be shifted (e.g. smart devices or timers). The report considers the *network perspective* and the technical and economic factors that relate to individual households, but the data and assumptions behind the CBA are unfortunately not set out in detail.

Regardless of whether a CBA is applied to the electricity sector or to an individual consumer, the steps in method are the same, and is usually followed by a qualitative judgement. For example, the consulting firm Jacobs was commissioned to produce the CBA report for the *Council of Australian*

Governments (COAG) *Energy Market Transformation Team*. This COAG CBA methodology describes the standard CBA steps, followed by a qualitative assessment (Parisot & Freund, 2017, p.43) which mentions uncertainties in assumptions (2017, p.49) and risks (2017, p.55). However, the assumptions only apply to the network level and not at a householder decision-making level, which is the gap that this paper addresses.

Overall, it is acknowledged here that social researchers are justified in the assessment that CBA is limited and flawed and that categorically different values may indeed be incommensurable. An awareness of the methodological process; what the weaknesses and strengths are, and the circumstances in which it is appropriately applied is vital. Critically, where the type of decision-making centres on cost — the CBA method should be appropriate. The simplified or quasi-CBA calculators exampled by Table 7.1 indeed provide a useful heuristic; however, this is only partial factor in consumer decision-making. For example, weighing up the costs and benefits of home battery storage, an article in The *Australian Financial Review* outlines that it is the 'non-financial pluses' such as a sense of environmental responsibility or grid independence that are influential (Potter, 2017). These non-financial elements, and reliability of electricity supply in particular, are discussed in detail below in the results section of this paper.

As a decision-making tool, a typology of problem structures is first briefly outlined, and it is explained where CBA fits in relation to these typologies.

7.2.3 Decision-making typologies

To understand if a CBA method is a suitable approach for a given problem, it is important to first understand how decisions are made, and what type of problems they relate to. Reviewing problem structures is useful to assess the circumstances in which a CBA-decision-making is applicable.

Typologies of problem structures

Hoppe (2011) defines a matrix of problem structures in his book 'The Governance of Problems' and this matrix was devised from simplifying earlier work of Thompson (1959) and others. Hoppe presents a typology of problems that stem from two parameters — where the problems sit on the spectrum of *certainty*, and where on the spectrum of *agreement*, as seen below in Figure 7.1.

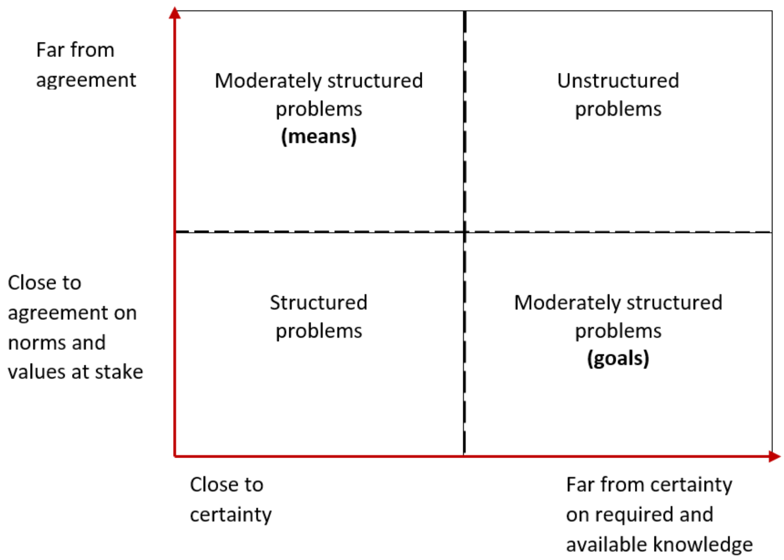


Figure 7.1: A simple typology of problem structures. Modified after Hoppe, (2011, p.16)

Figure 7.1 demonstrates a governance of decision-making typologies, and it is argued here that the logic of these typologies applies with equal validity to individuals as to organisations or policy decision-makers.

Wallis, and Harwood et al, (2015) add to Hoppe's typology of problem structures (2011) by refining the definitions, and for computational issues, of which it is argued the CBA addresses and the CBA sits neatly in the bottom left quadrant, as seen in Figure 2 below.

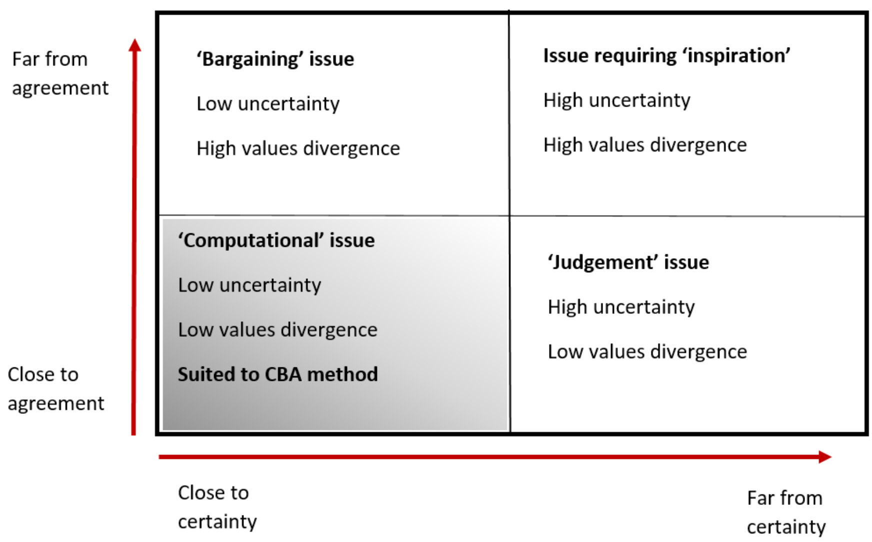


Figure 7.2: Issue types and associated objectives. Based on Wallis and Harwood et al (2015, p.106).

In summary CBA is best suited for issues of a 'computational' nature, and therefore, it is not suited to problems with political, non-fungible, and intangible values, which call for 'the need for principled compromise' (Richardson, 2000, p.990). It is understood however, that the CBA methodology attempts to contain problems which include the political and intangible aspects — so that the CBA application best suited *in theory*, rather than in practice. Measurement is important, but CBA practitioners should be careful of over-extending analysis; and CBA results that are read with caution and judgement are more likely to yield sensible results. Therefore, it is suggested that CBA is theoretically an appropriate methodology for assessing the financial outcomes of battery system installation, but that *in practice* it is often misused.

According to Figure 7.1 and Figure 7.2, the CBA is logically situated at the bottom left-hand corner of the diagram — that is, it is suited to the confines of problems that have a technically rational decision-making basis. From this, theoretically at least, CBA appears to be suited as a decision-making tool for householders in whether to purchase a home battery management system.

It is important to qualify from a social science and policy perspective that these types of decision-making categories do not directly address equity as part of the overall logic. However — equity-type problems are arguably central to social scientists and policy advisors. Further, it is arguably a moral duty of academics and practitioners alike to also approach problems through an axiological lens. Referring more directly to the Figure 1 above, and specifically box 'structured problems' — this aligns with 'technically rational decision making' (Hoppe, 2010, p. 129) — it is noted that this type of problem is the simplest type. The reason for this is that close agreement and low uncertainty problem-types (i.e. computational types), lead to unambiguous, agreed-upon decisions. This paper details the limitations as discussed in relation to the CBA method in the appendix and discusses the types of limitations in Section 4.3.

In summary, an assessment of the value and the flaws of the CBA methodology has been provided in this section. The short-comings of the CBA methodology are acknowledged, while also recognising the usefulness of the method for computational problem typologies. In theory, for householders that value the economic performance of the system as a key interest, (i.e. saving money on bills) then a CBA is suitable, the system itself being technical and with financial characteristics (i.e. its' capability is to trade).

7.3 Methodology and approach

Thirty-four households on Bruny Island, Tasmania, were involved in the pilot and each household had a smart battery system installed and agreed to participate in longitudinal social science research. The householder recruitment was conducted by the incumbent utility and was random excepting three main criteria; that the participants 1) had stable internet connection to run the software 2) contributed at least AU$2,000 towards the systems to encourage a sense of ownership, and 3) were by preference permanent residents rather than 'shack owners'. The technical systems installed comprised solar PV, internet-enabled battery, inverter, trading software and experimental software for individual battery coordination.

The method for this case, similarly for any CBA; required a list of upfront and ongoing costs and a list of financial benefits over a ten-year period, and involved using a discount rate to bring future values to a common value.

One household in the study was selected for detailed CBA analysis. The participant case study (coded BT112) was used because they voluntarily provided the additional required information and details that were beyond the scope of the main CONSORT study, in order to make the calculation possible. The participant BT112 responded to an email request to all CONSORT participants by the author. BT112 comprise a retired couple (similarly to many of the cohort) that are regularly at home during the day use and so they can use energy during the day when it is being generated. The couple would be expected to have a small usage compared to a large, younger family demographic. It is noted that there is possible bias and limitation that this household volunteered, and these participants may well be more attentive to costs and benefits than others in the trial. However, the case study BT112 is not seen as exceptional among the cohort, but rather, likely to be generally representative.

The data for this paper includes interviews of the CONSORT participant for the case study (BT112); interviews of other CONSORT project partners and more widely; data from the incumbent network utility TasNetworks reports and other data as listed more fully in Table 2 below. As part of the wider CONSORT social science research team, interviews were conducted of the 34 participants (householders) and some of this data is referred to in the results section.

The final CBA result is a product of a modified spreadsheet with the formulas embedded that include the feed-in-tariffs and net present value, as designed by a CONSORT researcher, power systems engineer — Associate Professor Evan Franklin.

The cost-benefit analysis (CBA) determines a benefit to cost ratio of a hybrid battery system for participant BT112 of the CONSORT trial on 2017 prices and costs, reflecting when the system was installed. To undertake this CBA, data sources were consulted as listed in Table 7.2.

CBA data sources consulted
Pre-installation interview transcript (as conducted as part of the social science team)
The participants' installer quotations for the system and their estimations of costs and benefits based on the system configuration, capacity, previous bills and postcode (solar insolation for Bruny Island's latitude)
Email and telephone communication with the participant relating to internet costs and post-install bills
Data from TasNetworks on outage payments and bill costs (received)
Government reports; Scholarly articles; News articles; Company documents; An economics text (*Managerial Economics,* Keat et al, 2014)
Tested method assumptions and sought advice from industry experts, familiar with CBA: PV and FiT advocate, board member of the Tasmanian Renewable Energy Alliance, Gilding (TAS); Smart grid energy economist and researcher, Chapman, (USyd); Innovation utility engineer, TasNetworks, Jones (TAS); and Utility economist and consultant, Leitch, (NSW), Franklin (UTAS) Power systems engineer.

Table 7.2. Data source list for BT112 CBA

In summary, the case study data focussed on the example participant (BT112) who provided additional information and the data included recorded interviews, system data, and interviews with two grid economists and two utility engineers.

7.4 Case study findings

The overall ARENA social science findings relating to financial issues are first briefly discussed here, to provide wider context from across the full cohort of CONSORT households; and then the detailed analysis of the CBA analysis of the household case study for this paper is presented.

Key lessons that were reported to ARENA by the social science team in their final report include that the context of Bruny Island is not a typical 'early adopter' context. This is considered useful for industry and government policy learning as in terms of understanding mainstream adoption and transition. It was found that non-financial values were indeed important, including reliability (battery backup) which was sometimes considered more important than financial considerations due to the rural context of comparatively lower electricity reliability. Finally, it was found that householder participation in battery adoption is uncertain (Watson et al., 2019, pp. 7-8)

The findings focus on the householder perspectives on the value of the smart-battery system, where 'financial considerations were important, but we also found a range of other issues and motivations to be important, such as battery backup, and community and environmental values' (Watson et al., 2019, p. 7). In particular, the value of reliability was significant due to the rural context —

> 'A key tension in the Trial was the value householders place on having backup power available from their battery. It was expected by our industry partners that householders would be happy to share their battery with the network if they were well paid for its use, but our findings suggest this is not necessarily the case.'
>
> **(Watson et al., 2019, p. 7)**

In addition to the value of reliability, the social science team found that the longitudinal nature of the pilot allowed more discussion on the non-financial values such as 'community values' or environmental/sustainability values towards the end of the pilot than were expressed near the beginning when cost was discussed as a higher priority (Watson et al., 2019, p. 32). This finding was unpredicted, and it is noted that it cannot be captured by a pre-installation householder-CBA. Reliability in terms consumer values is discussed in greater detail, ahead in Section 4.6.

7.4.1 Decision-making CBA typology for CONSORT participants

An example of early householder/participant decision-making was evidenced in the pilot's pre-installation interviews, in answer to a question about motivations for being part of the pilot. Twenty-four households (70%) cited reducing bill costs or financial benefits as the primary motivation of being involved in the pilot. It was also found that some householders on the island were primed and on the brink of investing in PV-smart-battery systems and were waiting for battery prices to reduce, indicating economics is a key decision-making driver. In addition, focus groups conducted by the University of Tasmania social science research team on Bruny Island in September 2016 found that cost was an important decision-making factor for prospective pilot participants. The ten households (30%) that cited non-financial benefits as being the primary motivator included cited these non-financial benefits as relating to reliability, back-up and self-sufficiency (six), environmental reasons (two), and interest and being an early adopter (two). The case participant of this study (BT112) fell into the cohort of reducing costs as the primary motivator.

It is argued that, in terms of relating to decision-making typologies in Figure 1 and 2 to the pilot and to BT112, that the pilot had a high level of certainty (a specified subsidy/incentive; access to information and technicians) and hence a 'low values divergence' between the project offering and participants decision-making is assumed.

Overall, it is argued that the CBA method is a relatively suited method for residential battery energy storage system (BESS) applications and a CBA is applied for participant BT112 in this section. As noted above the householder logic — prior to installation, participants appeared to be finance-centred. However, over time and with closer analysis, it became apparent that there were other additional non-financial logics or values.

7.4.2 Cost-Benefit Analysis of a Residential Battery Storage System (Participant BT112)

As discussed, the participants (BT112), are a retired couple and are permanent residents. They also live in a township (however, not connected to mains water), and the semi-suburban rather than a bush-fire prone setting is influential in their sense of a value of battery backup compared to other participants that assigned their battery backup circuit to water pumps. The couple were cost-conscious, and they were 'very interested' in saving money on electricity bills according to their pre-installation interview (29th Nov 2016). Despite this attentiveness to cost, it is noted that the battery backup was an important value and issue for BT112, as with other participant householders due to the rural context, noted above. The value of reliability is investigated in more detail in Section 7.4.5.

The household-CBA for these participants is now outlined. Table 4 below provides a guide to before and after system installation costs and benefits, reduced to equal terms, by dollar value. To calculate system costs and benefits, a Net Present Value (NPV) was calculated for each item by applying a discount rate of 5%. This value was arrived at after deciding it is most appropriate for householder decision-making to apply their mortgage rate as the discount rate. The participants (BT112) were asked what their banks' mortgage rate was, and the variable rate for their bank was *'very close to 5%'* (BT112, interview, May 2018); thus, this 5% figure was applied. However, in interviewing experts within the industry on this point, it was found that the choice of discount rate was rather contentious and variable. A high discount rate means that the benefits are more rapidly discounted over time than a lower discount rate estimate. This indicates that a higher rate is 'pessimistic' compared to lower rate as 'optimistic' in terms of applying a householder-centric CBA. The choice of discount rate is indeed controversial among economists (Zhuang, Liang, Lin, & De Guzman, 2007, p.1), and this was the case for the energy economists interviewed. The grid economists' view of high 'risk' lent towards a high rate (>9%) (Chapman, 2017), while the utility economists' view of that assessment was one of 'undue pessimism even at 7%' and he lent towards a lower estimated rate of 5% (Leitch, 2017), and then there were the very low smart-battery company values (2-5%) (Sonnenflat, 2016), and the low NSW government smart-battery CBA values. Choosing a social discount rate is considered problematic, uncertain and contested (Freeman & Groom, 2016; Paulden, 2014; Weitzman, 2009) and so this somewhat arbitrary choice of discount rate is emphasised here in relation to conducting a householder-CBA as an important assumption, which is hidden if one only focuses on the final CBA value. For this exploratory action-research CBA exercise, the choice of a 5% discount rate for the householder was judged to be a practical one to use because it was the same as their mortgage rate, and as a battery system payback is likely to be at the same or similar rate.

The levelized cost of electricity (LCOE) was disregarded, although it is used for energy network CBAs, as it is argued that consumers do not 'care' about the network, 'they are not interested in weighing up alternative modes of generation' (Gilding, 2017) and network costs can be thought of as *external* to householder values. In addition, LCOE is ordinarily applied to large-scale electricity infrastructure planning — which is not of relevant interest to our participant, hence it is not considered.

Turning now to specific householder data, for participant BT112, the system specifications and costs expressed in Table 7.3 below, are then inputted into Table 7.4 which is described in detail below.

LG RESU 10 – LG Package 4.48kW system (LG 9.6kWh battery) and 14 LG320 watt solar panels.	
Battery capacity	4.48 kW / 9.3 kWh
Total quote value	$19,599.40
Subsidy value	$16,000 (based on $3,200/kW of battery capacity)
Customer contribution	$3,599

Table 7.3. Lithium battery specifications for BT112

Within the inputs section in Table 7.4 below — all fixed factors are represented such as the discount rate, system cost, internet costs associated with the 'smart' system, the size of the PV and battery in kW; an average annual generation (for Bruny Island's latitude); with a 0.5% PV system degradation (slightly diminishing generation); a rate of self-consumption with the battery (70%); with current Tasmanian tariff prices, as well as the estimated payments from TasNetworks for payments on an annual basis for network support, and the AEMO's calculated VCR ($28.56kWh) value for Tasmania.

The initial, year 1 costs include the quoted value of the system, minus the subsidy, plus the internet costs, with subsequent years with zero capital cost and only the internet costs as ongoing.

The system specifications are already given and battery efficiency of at least 80-90% is common for residential lithium batteries (Queensland Government, 2018b; Rodriguez, 2017).

The upfront costs were $19,599 for the entire PV battery system, and ongoing costs associated with internet for the battery at $15p/m. The annual generation can be estimated by ABS and APVI statistics on solar insolation against latitude or postcode/region, for example the Bureau of Meteorology's average annual sunshine duration and exposure maps (Bureau of Meteorology, 2016a, 2016b). These figures in Table 7.4 (as described above) are inputted for the calculation in Table7. 5 below. The resulting CBA estimation is a cost-benefit ratio of 1:2.64. This indicates that the economic benefit of purchasing this system, over a ten-year period (with the assumptions listed) is 264% greater (at net present value) than if system were not installed. For a 2017 subsidy of $16,000 the ten-year benefit is 2.64 times greater than the costs as presented below in Table 7.5.

CBA BT112 Inputs	
System Finance	
Discount rate	5%
Total cost	$19,599
Subsidy	$16,000
Net cost	$3,599
Internet	$15 p/m
System Size	
PV size	5 kW
Battery power	4.48 kW
Battery energy	9.3 kWh
Battery efficiency	85%
System performance and tariffs	
Annual generation	1300 kWh/p
PV system degradation	0.5%
Non-battery self-consumption	30%
With battery self-consumption	70%
Average import tariff (T31)	25.9 c/kWh
Export tariff	8.9%
Other financial benefits	
Network payment (TasNetworks)	$150 pa
VCR	$269 pa

Wholesale participation (Reposit Grid Credits, VIC)	$0 pa

Table7. 4. CBA BT112 Inputs

CBA outputs for BT112 – Combined PV/ battery system (including project subsidy)			
	Discounted benefit (2017 terms)	**Discounted cost (2017 terms)**	**Benefit to cost ratio**
10-year CBA	$13,335	$5,058	2.64

Table 7.5. CBA outputs for BT112 – Combined PV/ battery system (including project subsidy)

However, all else being equal, for no subsidy, the system is not break-even. The benefits are at approximately 63% of the costs, as per Table 6 below.

CBA outputs for BT112 - Combined PV/ battery system (without project subsidy)			
	Discounted benefit (2017 terms)	**Discounted cost (2017 terms)**	**Benefit to cost ratio**
10-year CBA	$13,335	$21,058	0.63

Table 7.6. CBA outputs for BT112 - Combined PV/ battery system (without project subsidy)

This means that in 2017 terms, the PV and battery system is not yet economic. Solar PV without battery remains strongly economic however; and with rapid learning rates, it is anticipated that batteries would be break even in under a 20-year time frame.

7.4.3 A description of key CBA assumptions

The categories of assumptions observed that underpin the CBA fell into five categories; 1) calculative assumptions 2) pace of technological innovation 3) warranty timeframes 4) feed-in-tariffs and 5) the value of reliability in the Bruny Island context. These are explained in some detail below, and the assumptions are listed in full in the Appendix.

Some of the assumption types relate to calculative ***estimations*** — for example, estimations of average previous bill costs; forward estimations of solar generation based on the insolation profile for Bruny Island, and therefore an estimation of bill savings due to an average, estimated storage availability and trading. Other assumptions took into account the ***rapid pace of technological innovation*** in lithium technology and therefore expected trajectory of falling costs over time, and so that the generous subsidy value was not included in the CBA. Not counting the subsidy (Table 7.5) provides a 'head start' in predicting ahead ten years (or less) for decreasing battery costs, but it also reflects the reality of the householder in this pilot.

Householders in the pilot had a minimum contribution to the trial of $2,000 to encourage a sense of ownership within the project design — and participant BT112 chose to contribute an upfront cost of $3,599 to purchase their system type. Other assumptions related to technical behaviour of the components and ***warranty timeframes*** — for example, the CBA is set over a ten-year timeframe because the battery warranty is 10 years. It is likely to be operational (with some battery fade) well beyond ten years, though no lithium household battery system has been around long enough to exceed a warranty. Additionally, the warranty for the solar panels on BT112 are for 25 years (and are also expected to be functioning after this period). Also, replacement of the inverter is not factored in at 5 years (warranty length) as according to a number of experts in the field it can easily be expected to last more than 10 years (for example, Gilding 2017, Leitch, 2017, Franklin, 2018) so overall, the CBA timeframe is conservative. In terms of the Australian policy environment, small-scale renewable energy certificates for solar systems (STCs) are being phased out and reduce every year. These STCs reduce the capital costs of PV and the value of these fluctuates on the spot market. At the time of the participants' installation each solar credit was worth $36.40 which amounted to a rebate of $2,875.60 for 14 panels (5kW). Tasmanian ***feed-in-tariffs*** were also undergoing a change at the time of installation, from T31, T41 to the new time-of-use (ToU) tariff T93 and though the impact of these changes is expected to benefit smart battery owners this complexity of change-over is not captured by the CBA. It is noted here that although the power of the CBA is that it can simplify the issues of the FiT to a precise numerical value, that a CBA cannot capture these sorts of changes (changes in tariffs), and so a CBA result is not fixed over time for current battery systems.

In summary, the results of the case study CBA of a before versus after installation for a ten-year period yielded a benefit-to-cost ratio (BCR) of (2.64:1), meaning that the benefits of system installation outweigh the costs by 264% compared to the status quo (prior to installation). This result is acknowledged to be significantly underestimating the real BCR because it does not take into account the ongoing benefit of switching to the time-of-use tariff (ToU) over a longer timeframe.

The ToU data was not available at the time of writing in relation to the case study. Additionally, as mentioned above after the 10-year period, benefits would continue to increase as electricity grid prices rise. However, the final report to ARENA found that switching to ToU was economically favourable for those who had switched; households that switched to ToU 'were significantly better off financially in relation to Reposit component of the solar-battery system for households who had changed to the ToU tariff, compared with those who stayed with their existing flat-rate tariff' (Watson et al., 2019, p. 37). Interestingly however, almost 40% of households (13), decided *not* to move to a ToU tariff, in part because of the confusion surrounding the change and steps needed to initiate the change from the consumers point of view, and the lack of coordination and communication between agencies (Watson et al., 2019, pp. 37-38); namely, communications between the participants and the installers, project's ICT firm, , the transmission utility, and the retailer.

Finally, there are assumptions related to the value of ***reliability*** within the Bruny Island context; namely that a *high* value of customer reliability (VCR) is maintained — the value reliability is expected to be higher than mainland Tasmania because of the rurality and immediate impact on water supplies (pumps) – especially in summer for protecting houses during bushfire emergencies. Installing a battery could reduce the impact of bushfire risk on the house due to pumps replying on electricity – therefore the high, AEMO-formulated, NEM regulated VCR is maintained.

One of the assumptions, reliability, is now explored in detail, as observed within the CONSORT trial.

7.4.4. The value of reliability — The case of Bruny Island

To set a general context, wider findings from the pilot showed that reliability was significant for most participants. Reliability or 'battery backup' was important with one-third of respondents (11 of 32) selecting the answer 'to store power for later use' as the most important value, while secondary factors included 'to help manage/make the best use of our tariff/s' and 'to store power for backup if power goes off' (Watson et al., 2019, p. 33). It is noted here that storing power for backup is more important for rural areas where electricity reliability is not as high as urban areas. Managing tariffs is directly related to a focus on cost (bill savings) and 'storing power for later use' is asserted here as a mixture of a focus on cost (arbitrage and changing tariffs) and backup/reliability.

Reliability was found to be an important complexity as it relates to CONSORT participants, including the case BT112. Bruny Island is not connected to mains water, and all water for the island's residents is powered by pumps and rainwater or a bore water hole in the back garden, in the case of participant BT112. Reliability of electricity in this situation means that if power is interrupted, then the water pumps no longer work that are used for the house (e.g. toilets and taps), but also for use in the case of bushfires. BT112 is located — within a township that is not at the same perceived risk of bushfire than those householders more rurally sited; i.e. reliability was perceived as higher for others within the cohort. Overall, reliability is argued for these reasons to be more valuable in this rural context than for urban counterparts.

The value of reliability is an important issue, for networks and for householders and is deserving of close consideration. This was a more complex issue than expected and deserved attention. Examples of the common commensurable aspects of value of reliability would include the value of goods in freezer fridge, or for a backup circuit, or for self-sufficiency, or how much people would be willing to pay for reliability, converted to a market value.

The author was kindly provided access to the utility outage data for Bruny Island, and asked the householder 'willingness to pay' (WTP) questions to gain an indication of an individual value of reliability. The response was that if they were not on the pilot, they would be willing to pay an additional $7p/m only on their bills to avoid outages ($84 annually). However, in their mind the Bruny outages, of even up to half an hour are not considered severe for them. Severe for these island customers means 3 days in summer with defrosting food, not a winter outage. The winter outages for Tasmania are the network peak costs, and the WTP as an indicator of VCR is not factored into the CBA as it is a hypothetical.

7.4.5. The householder perspective of reliability — storage against state of charge

There is another way of looking at the value of battery reliability to the customer — a householder could reasonably be imagined to question *"So what might the maximum value of my battery storage be? And further, what might it be in depending on how full my battery is at the time it is called upon?"* The maximum value of the battery if it is called upon, as a service, would be in *extreme* circumstances — such as an unplanned outage during peak demand.

To answer this, it is argued that it is reasonable to apply the NEM regulated (Value of Customer Reliability) VCR, and for Tasmania it is $28.58/kWh. The economic value of the battery can be related as a dollar per kWh for the range of battery storage, or state of charge of the battery. This concept is outside of conventional tariff trading, NSPs, and grid credits, and represents a theoretical value of the BT112 battery. As seen in the graph below, this value is in the order of $274 for a full battery. In summary, theoretically, for the customer, a 9kWh battery at full charge is worth $274.38 (factoring in VCR) and the battery reliability during an outage is approximately 1 hour 55 minutes to 90% depth of discharge (DoD). This assumes that the DoD cannot exceed 90%, which is 0.96kWh which is rounded to 1kWh. The value of reliability (backup) is described in the box below (Figure 7.3), then graphically in Figure 7.4.

Theoretical value of a full battery for reliability (back up)
The regulated VCR is $28.58 kWh – applying this as an 'extreme outage' the value then the value of backup that the battery could provide based on a capacity of 10kW battery can be calcuated. This could potentially be related an *internal* (householder) value of customer reliability. *For example,* How many hours could a battery run at an energy consumption of 9.3kWh with power capacity of 4.48kW. Hr= kWh / kW = 9.3kWh/4.48kW= 2.07 hrs If the battery is 9.3kWh capacity, and the VCR is $28.58/kWh, then the value of the battery is 9.3kWh x $28.58/kWh = $ 265.79 [from full charge]

Figure 7.3. The maximum value of battery storage

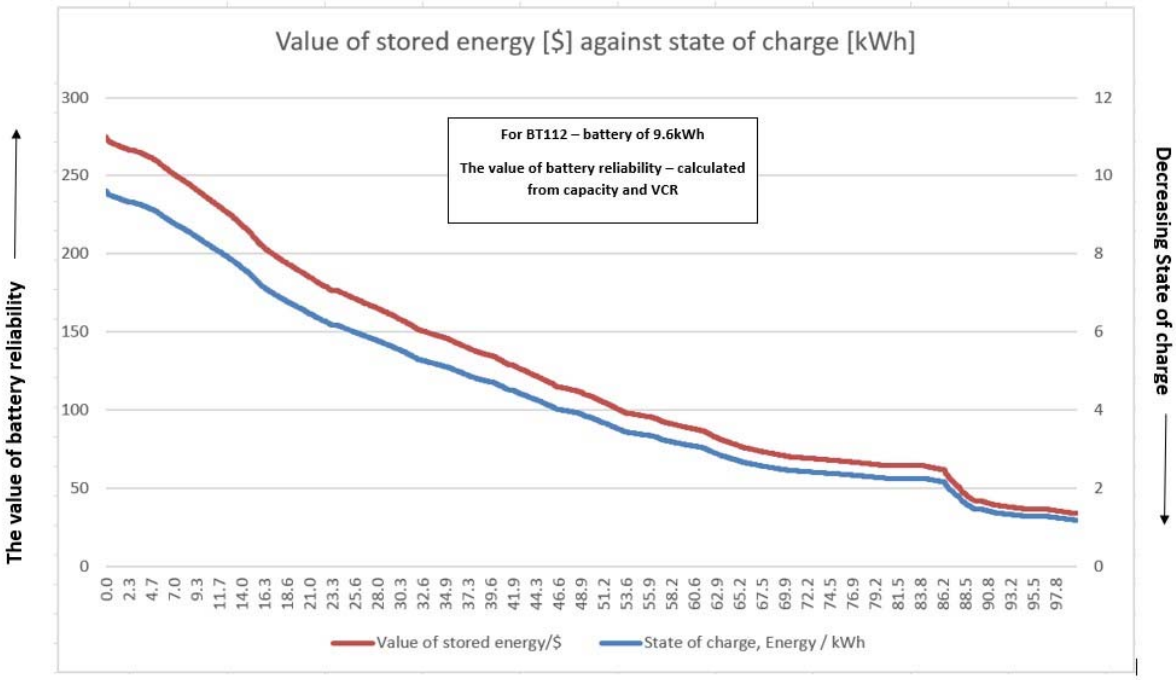


Figure 7.4. The value of battery storage related to state of charge.

The results here are related to the context of a 9.3kWh battery on Bruny Island, Tasmania and serve as an example only, however the value of reliability is important for all householders and the energy system, though householders in urban areas may not be as acutely aware of the impact of variable electricity reliability.

Reliability can have different meanings from a network perspective compared to what an energy consumer of CONSORT pilot participant values. The Value of Customer Reliability also has planning, investment and political dimensions. The addition of batteries to solar PV — is effectively integration of the prosumer — adds a new level of complexity in terms of what reliability provides and means to the prosumer.

From an energy consumer point of view, and specifically for Bruny Island CONSORT participants — who are prosumers, reliability is multi-faceted; it encompasses and has consequences as described in Table 7.7 below.

Prosumer perceptions and consequences of energy reliability	**Issue category**
A perception of battery 'back up' in the case of an outage (e.g. a 'storm setting' referred to in post-install interview BT108)	Security and reliability of supply
Operation water-pumps for the house (this was a most important aspect of reliability for most households)	Safety; particular to CONSORT and some rural contexts
The ability to have a level of self-sufficiency (e.g. post-install interview BT112), for example having a dedicated circuit in the house (eg for computers)	Self-sufficiency
A continuity of supply when there is an interruption to grid supply (UPS; though this was not an issue for many householders in interview)	Convenience and utility: security and reliability of supply
Reliability internal to the smart-battery systems – e.g. the Reposit-Solax compatibility issue, and reliability related to Reposit 'picking up on' tariff structures – software reliability and trading reliability (e.g. BT104, BT117, BT118)	Reliability issues related to new technologies and integration
Reliability as battery back-up and customising a set DoD (depth of discharge) and is a form of participant agency though is not discussed here	Agency and control over DoD settings of the smart battery
Concerns that that the battery system is not behaving as it should be, a sense that the technology is unreliable (e.g. post-install interviews BT118, BT104, especially in the 'teething-stages' of the pilot roll out)	Issue of trust: that the technology is behaving in the prosumer's best interests
Concerns that a lack of householder control to be able to change settings on the battery means they feel they have less reliability in battery behaviour than they would like (e.g. post-install interview BT132, and others that expressed a desire for more control or agency)	Mismatched / unmet expectations of agency and control of battery behaviour

Table 7.7. Prosumer perceptions and consequences of energy reliability.

From an electricity network point of view, however, perfect reliability implies a continuous supply of interrupted power. The levels of reliability are regulated through the GSL (guaranteed service level) and outage payments to consumers where this is breeched.

In summary, the value of reliability is high for the Bruny Island participants, and this is likely transferable to other areas within the NEM that are edge-of-grid or rural with frequent outages. Importantly, as mentioned at the start of this section, the meaning of reliability varies and therefore is difficult to equitably capture within a CBA.

7.5 Discussion and Conclusions

The novel contribution of this research article is that it brings a social science perspective of consumers decision-making on residential energy storage within an empirical case. In addition, the framing of a householder-CBA perspective contrasts with an area dominated by energy system-logic and perspective of CBA decision-making. The analysis of assumptions of a real CBA at a micro level within the energy industry is significant because residential storage is a current issue and an important driver of system transition.

A detailed CBA methodology for decision-making is not ordinarily employed by householders, although an intuitive or simplified calculation of costs and benefits was seen as attractive to most participants in CONSORT, and such CBA-like tools are promoted by solar-battery companies. Importantly, the type of (grid-centred) assumptions by networks and governments infer a residential CBA as an indicator of the rate of deployment, where this may not be the case, and other drivers exist which may accelerate or hinder transition. As consumers are pivotal to transition, a research gap is perceived — specifically in the space where network-paradigms on decision-making intersect with householder decision-making.

In summary, this research paper addresses a conceptual gap between current thinking of decision-making from a householder perspective compared to systemic decision-making logic that is typified by a CBA. The energy system: the network, government and business CBA-logic infers the consumer drivers of the energy transition towards smart batteries. The system-logic of decision-making for the residential sector purchasing batteries is centred entirely on economics. It is argued that stakeholders within the energy system, including battery manufacturers and network businesses may not be applying an appropriate frame of reference to understand drivers of consumers relying on CBA analyses alone.

A householder perspective is attempted by applying a CBA as a common decision-making tool that is routinely applied within the electricity sector, by government and business in relation to consumers. It is applied to the householder whilst also analysing and critiquing the method itself. The empirical data for this research drew from the CONSORT smart grid case with focus on one participant. The case BT112 was examined through the lens of the social science scholarship that relates to commensuration, equity and CBA analyses; against the background of government reports. The framing of this research is underpinned by the scholarship on the governance of problems; and decision-making typologies — because it is context that defines the appropriate application of various decision-making methods.

A householder-CBA was applied and some of the tensions and difficulties of the methodology were illustrated. For example, householder interview results through CONSORT highlight factors such as self-sufficiency, environmental responsibility that are likely important drivers in relation to smart battery uptake more widely. For the case BT112 cost was a primary factor. For this study the CBA for BT112 was calculated as favourable for subsidised systems, with solar PV alone remaining economically favourable. For the participant without the project subsidy the CBA is currently uneconomic for a smart-battery system. CBA is an indicator, but it is not the whole story on decision-making at the household scale.

It was argued that the CBA methodology is suited overall to householder decision-making on solar and battery systems with the aspect of reliability difficult to capture. This paper defended the use of CBA as a legitimate decision-making tool, and this is a somewhat unusual sociological perspective, given that social scientists commonly focus on the CBA failings. In contrast, this study argues that to focus only on the method's limitations infers that it is being routinely or dangerously applied inappropriately, without consideration of context.

The key criticisms of the CBA methodology were outlined but the method itself is defended in principle, when two conditions are met: 1) that it is applied transparently, revealing the underlying assumptions and 2) that the CBA methodology is applied in the context for decision-making that centres on economics. In reality, unfortunately, it is noted that the real-world context of how CBAs are applied are not able to live up to full transparency and to be applied in a context without politics, power and underlain with assumptions, including the intangibles and values outside a CBA. The complexities and uncertainties of the CBA as a method has been interrogated, and overall, for the context of decision-making for a solar-battery system, it is found that non-financial issues are important, especially reliability in the case BT112 (and for others) and that CBA remains a useful tool in the process of decision making, alongside other values.

In terms of logic of decision-making typologies, CBA will continue to be controversial, because it was designed to take social value into account, which is in categorically is at odds with commensuration, therefore it is difficult in *practice* to equate the social and the financial. It is argued that in the final analysis of a decision that relies on a CBA should routinely be followed up with an informed qualitative judgement. Social concerns remain; that the estimation of public utility using CBAs appears to be consistently low according to some theorists (Maneschi, 1996, p.411), and that 'willingness to pay' relates to equity issues because there may be an inability rather than willingness to pay from an energy equity viewpoint.

Residential energy consumers are recognised as a being pivotal to accelerating a stabilisation of a partly decentralised electricity grid, or 'transition.' Therefore, the residential-CBA perspective was deserving of attention as householders are key drivers of energy system change in whether households will commit to and adopt battery storage.

More widely, in terms of scaling-up, CBA may not be a good overall predictor of when batteries enter the mainstream, due to other non-financial drivers external to CBA analysis such as self-sufficiency, reliability and environmental reasons. An increasingly distributed and hybridized-grid in the future, and the power of consumer decision making will be central in driving change; with decision-making not fully revealed with CBA methodologies.

7.6 Policy Implications

The findings of this paper recognise the potential power of the CBA because there is scope to hide a lack of knowledge and incorrect assumptions, and so an ideal CBA approach is one of full data and high transparency. It is argued that many Australian households are unlikely to seek out additional information but may trust in the online simplified tools provided on government websites. Significantly, householder decisions on battery systems will be site specific (e.g. the rural context and reliability) or be connected to other values (e.g. those of sustainability, self-sufficiency) that will also affect the rate of electricity system transition in a somewhat unpredictable way — in reality.

Although comprehensive data and transparency may appear unrealistic goals, recently these tools have arrived in a simplified online form, are made available by some Australian state governments (in addition to businesses) who are attempting to scale-up the implementation. If a deliberately accelerated transition is to occur though, schemes would probably need to move from a state-based to federally supported. The Federal Government could incentivise a national smart-battery scheme and provide detailed, transparent data so that potential prosumers can be more fully informed in their decision-making.

In terms of the issue of reliability, for decision-making on residential storage, this is somewhat addressed by governments that subsidise batteries on social housing and target social inequity in relation to the implementation of this technology. Rural, edge-of grid households place a relatively high WTP on reliability, and in terms of equity, a WTP does not reflect the ability to pay based on household circumstances, so it is suggested that to increase energy equity in the transition to higher DER, that a variable WTP for rural and urban, and high and low income housing be considered.

Appendix — CBA Assumptions

A1 List of assumptions for the CBA specific for a CONSORT participant

Assumptions that are specific to BT112
Applying subsidy because 1) it reflects the participant reality 2) due to rapidly dropping system costs, this acts as projection into the future where capital costs are not prohibitive.
Costs as of Oct 2016 (installer quote). Prices may have reduced since the quote for new installs.
The upfront capital costs included in the subsidy comprise: 14 solar panels; the inverter; the battery charging unit; an interface for the inverter; the battery (LG 9.6kWh); the smart interface; labour; minus the solar credits. The solar credits are a commonwealth subsidy which the customers choose to either have reimbursed or allocate the installer to have reimbursed off the capital costs, it is part of the RET.
Bill cost of $600/quarter was obtained in a pre-install interview — and for the purposes of the CBA table it is assumed to be an "average" season in terms of energy use.
Upgraded internet service to $54.99, a "little higher" than the previous service. $10- $15/pm difference. To confirm exact difference.
Estimated value of PV power generated in one year is $1419.94 (year). This calculation by the installer is not included in the BCA table because the overall calculated savings off the bill - estimated at 65% of $600 is used as a higher-level proxy. To include this would be to double-count benefits: this is because PV generation benefits are already taken into account in the installer's calculation of bill savings.
The inverter replacement cost is not featured in the CBA. The inverter for BT112 has a warranty for 5 years. The model is a SK TL5000E Hybrid 5kW capacity inverter, costing $2,000 in 2017 dollars. Companies that sell battery PV systems do not include inverter replacement at the 10 year mark. Experts interviewed confirm that inverter life commonly exceeds 10 years.
Calculation as per participant's installer based on a 4.5kW system and an average of 3.5 hours of daylight throughout the year. The installer (I want energy) predicts a 65%, with more generation being generated over summer months, particularly December and January. The installer notes that the residential tariff introduced in July 2016 (Tariff 93). They advise that T93 could be beneficial for people with battery storage that can store the daytime generation for 'use in peak periods' (I want solar, 2016) website
LG calculator – LG is BT112's battery type and system brand https://www.lgenergy.com.au/solar-calculators/solar-income-roi-calculator But these calculations do not take into account a smart grid operation – i.e. optimising for trading at peaks.
<u>*A note on small-scale technology certificates (STCs) for BT112:*</u> BT112's 5kW installation was eligible for 79 Solar Credits @$36.40, totalling $2,875.60 which was paid to the installer as a government incentive and the customer paid the balance, the amount they were

paid was confirmed in interview and was listed on the quotation to the customer, with the option given to the customer (BT112) to either pass this amount on to the supplier (installer firm), or the quoted amount being reduced and the installer being paid directly.

A2 List of assumptions applicable more widely; for residential battery systems

Wider assumptions - These assumptions may be applicable to other trial participants; or more widely
The CBA breaks down into costs, rather than kWh. Firstly, costs are more relevant to the households, and secondly, *kWh is not a constant in terms of 'cost over time'* [significantly volatile, considering tariff structures]; while the time value of money is relatively constant over the time of the trial (3 years), $ is a constant for the purposes (economic resolution or granularity) of this CBA table.
Network support payments – these have been kept in the CBA table because it is *additional and separate* to the retail electricity bill and tariff structures.
$28.58/kWh is the Bruny Island participants measure of reliability based on the AEMO "Value of Customer reliability" survey of 3,000 residential and business consumers across the NEM in 2013 (AEMO Fact sheet, undated).
'LGC warrants and represents that the Product retains at least 60% of Nominal Energy for the either 10 years after the date of the initial installation' (LG Chem Lithium ion Battery, 2016).
Depreciation not taken into account for this BCA — *Sonnenflat* uses this assumption for its 10 year comparisons. A recent technical study on the *Tesla Powerwall* for battery fade, indeed resulted in 'not consider[ing] the replacement of the battery after the warranty period' i.e. assuming negligible capacity fade of the battery over the trial period (Truong et al, 2016)
Assuming no shading of panels (uncompromised efficiency)
Tesla claims zero operational costs once it is up and running, because it requires no maintenance, thus, the same applies for this CBA table (Truong, et al 2016, p.2)
The 'battery capacity is guaranteed to retain at least 60% after 10 years (ibid)
'It is important to note that a system lifetime *below* the assumed 20 years corrupts the achievable savings of the BESS' (ibid, p.3). The BT112 table assumes 10 years – so it is expected to be a minimum CBR (cost-benefit ratio).
The inverter's efficiency remains above 90% (ibid, p.4)
NPV inherently "discounts the future" in 'favour immediate benefits and distant costs over long-term benefits and immediate costs. This spurs development at the expense of environmental costs' (Schnaiberg 1980: 334-44). Even more fundamentally, 'pre-suppositions for commensuration often reflect assumptions about commodification that are inherently political and asymmetrical' (Radin 1996, Sunstein 1994, p.326).
Bruny Island would value reliability more than mainland Tasmania because of the volatility, rurality, and immediate impact on water supplies (pumps) – especially in summer for protecting houses during

bushfire emergencies. Installing a battery is a system that lowers some householder risks. I.e. battery back-up helps improve safety in summer for house and property (bushfire risk) — due to the fact that the backup circuits can select the water pump.
The CBA does not include other soft or social benefits including network benefits – but is focussed on the householder benefits – public good benefits such as reduced transmissions costs/delayed infrastructure costs/ CO_2 abatement/ increased jobs from emergent industry players in associated with storage and new smart technologies and SRE or other public good benefits – however it does seek to quantify reliability in the Bruny Island context and also includes health benefits.
Health benefits – these are to society, measured as a whole — and used to argue for increased FiT (Gilding, 2017b). Because they are 'not [yet] quantified with sufficient reliability' they are not yet included in FiT network CBA costs. However, *'the Australian Academy of Technological Sciences and Engineering, each kWh of solar PV that displaces coal fired electricity contributes 1.3c in reduced health costs'* (Gilding, 2017b).
Some economic analyses of residential BESS take into account the value, including all values to the network. My calculations relate only to the value of immediate concern to the consumer. This might be criticised, but I argue that the network CBA costs are well known by comparison to consumers.
I am not making an argument for or against network costs and values. I am taking the battery systems costs at face value to the prosumer.
Retail bills are commonly allocated a percentage of costs to generation, transmission, distribution, retail and environmental costs but as individual consumers –and within game theory – if they act as rational utility maximisers without consideration for the network, *then I don't take into consideration these expenses*, as in the 'real world' consumers would not altruistically incorporate network costs that they would not benefit from if they had a battery system and had the technical capacity and choice to go 'off grid' (Gilding, 2017b).
Notes on tariffs: Tariff structure comparisons (T31, 41 versus T93) are deleted from the BCA table as they are dealt with in total in the bill (ie usage+fixed) regardless of tariff. T93 peak 31.31c/kWh, 7-10am, 4-9pm M-F, all other times, including weekends 14.58c/kWh, and participants that can alter their behaviour to shift consumption from peak to off-peak times. The installer also notes that the effect of this tariff to optimise generation would also mean installing panels to face east and west rather than north as is currently the case "*There may be a case for new solar installations using this tariff to consist of east and west facing panels to increase solar generation at peak tariff times "* (Installer quote, Oct 2016) *"we are pleased to see that the residential tariff involves a significant price difference between peak and off-peak. We suggest you consider switching to the new residential tariff 93 when installing solar"* (Installer quote. Note that BT112 has switched to T93, though Reposit is "dormant")

For ToU tariffs in Tasmania p.26 https://www.tasnetworks.com.au/TasNetworks/media/pdf/our-network/PP002-Network-Tariff-Application-and-Price-Guide-(Approved)_2.pdf

Chapter Eight

Discussion and Conclusion

This chapter is structured as follows: First, a summary of the overall energy transition problem investigated in this thesis is provided. Second, the findings of the empirical chapters are presented. Third, the theoretical basis is revisited and synthesised with the cross-cutting themes that run throughout the thesis. Fourth, this doctoral research closes with the conclusion, highlighting the original contributions and broader relevance of the study.

8.1 The energy transition problem under investigation

This thesis grappled with an aspect of the energy transition problem which currently confronts centralised electricity systems around the world; namely, the destabilising high penetration of solar PV, the challenge and opportunity of the emergent residential energy storage sector and the utility response to the transition towards decentralisation. The lens to study an example of this transformation was provided through the CONSORT pilot.

As highlighted in Chapter One, the Australian electricity sector is under significant strain due to world-leading rates of solar rooftop PV driven by consumer preferences, in alignment with rising electricity costs, decreasing battery-system costs, and energy policy and climate policy pressures to accelerate transition. The focus on an accelerated transition brought complex tensions into focus: to encourage an accelerated implementation (of incumbents that face institutional inertia, while supporting new entrants), whilst also encouraging orderly governance of an accelerated transition during a time of disruption. This thesis demonstrates how prosumers, positioned to be powerful agents of system change, are central to transition. However, there appeared to be conflicting interests, whereby the prosumer interests appear at odds with the incumbent utility interests and even the interests of new entrant start-up companies. This tension of apparent conflicting interests was explored through the focus on agency and engagement as precursors to technology acceptance in Chapter Five and is referred to later in this concluding chapter. The tension between the utility-prosumer interests were also demonstrated in terms of the underestimated implementation delays and impacts on prosumers (Chapter Four); and the understanding of decision-making reaching beyond the economic (Chapter Seven).

Central to this doctoral research was a focus on understanding the changing relationship between the prosumer, the utility (incumbent), and start-up (new entrant), where it is argued that the arrangement of these relationships *constitute* the disruption (and post-disruption regime). This new relationship has destabilised the energy system (through the high rates of residential PV), yet also has the potential to improve the energy future system (through *managed* residential storage). Thus, an understanding of prosumers, and the interaction with future battery systems, as well as how networks might be able to adapt, is a central problem to address in the unfolding of a new hybridised electricity system.

Storage 'behind-the-meter' is already shifting utility paradigms and business models. More widely, a paradigm shift has been forced upon centralised electricity networks that have nevertheless had, for well over a century, time to refine the orchestration of a 'one-way flow' of electricity provision as a public good. The deeply embedded arrangement of electricity provision, and the models of governance and policy that support the electricity sector, are now at risk of being rendered obsolete in their current forms. However, modern society depends on the continued, stable, society-scale electricity provision that enables all sectors of the economy to function. As evidenced in the introduction to this thesis, the rate of change in the energy transition is also a disruptive challenge to the entire electricity system.

8.1.1. The lens provided by the case study

This thesis studied the ARENA CONSORT smart grid pilot, conducted on Bruny Island, south eastern Tasmania, between 2016 and 2019. The pilot was multi-disciplinary and multi-partner: undertaken by three universities; an energy network incumbent, TasNetworks; and software new entrant, Reposit Power. The pilot consisted of 34 households equipped with rooftop solar PV and 'smart' (internet-enabled) batteries that were controlled as a virtual power plant to support the grid (Bruny Island undersea cable) in times of peak demand. The research question for the CONSORT team as a whole was 'How do networks and prosumers combine constructively to meet their needs?' (CONSORT, 2015a, p.4). From a systems, management and policy-oriented perspective, this thesis asked the question ***'During a time of disruption within the electricity sector in Australia, how might the transition to smart grids be encouraged to be accelerated and governed in an orderly manner?'*** Underlying this question is the starting point of the theoretical basis of this thesis. Namely, ***'What conditions might enable upscaling, or innovative breakthrough to the mainstream?'*** This question was considered within the context of smart batteries in the Australian energy sector. Concepts of upscaling technological innovation, or transition, may be limited by the case study, but also may transfer to other technological innovations that are concerned with accelerating sustainable transitions.

The methodological approach of the thesis was described fully in Chapter Three. In brief, a mixed-methods grounded theory approach was used to plan, gather and analyse the CONSORT data. A theoretical framing was applied to the thesis and to the empirical evidence, in a top-down sense as a framework modified from the MLP whilst engaging with the policy implementation scholarship.

8.2 Summary of findings of the empirical chapters

8.2.1 Chapter Four findings in relation to SNM and Network Governance and pilot policy

Chapter Four first described the CONSORT pilot as the case study, and secondly asked '*How is the CONSORT pilot governed and implemented; and what SNM-like practices and processes were used?'*

It was found that the CONSORT pilot did indeed apply project-management practices known to successfully support innovative technologies and transition. The initial team building occurred in a manner that was typified by a networked governance structure, with interactions occurring across institutions, and cross-cutting hierarchies during the pilots' operational phase. An important finding however, and notably missing from CONSORT — as evidenced in Chapter Four, but highlighted Chapter Six — from an SNM perspective and learning, was the exclusion of the installers in pilot decision-making.

Networking and knowledge sharing include externally focused traits of SNM: reaching out to other networks to avoid "reinventing the wheel" and diffuse knowledge to build the niche. Knowledge sharing also occurred with discussions with other trial groups around Australia, government and ARENA trials, and industry-only trials. Learning was — for the most part — encouraged, and the inefficiencies and problems were tolerated, where in general 'egos were left at the door' (CONSORT Research Lead, 2018).

This thesis argued that the CONSORT pilot could reasonably be considered as sitting at the precipice of a niche movement becoming mainstream. CONSORT, and other similar ARENA projects, were funded by the Australian government (ARENA), and an incumbent utility — both ARENA and incumbent utilities are organisations that exist conceptually at the regime level as discussed — with the pilot being classified by ARENA as at 'TRL6-7', which is at a *demonstration stage just prior to upscaling*.

In summary, pilot findings related to both SNM and network governance. Key elements of SNM were observed, such as the protected niche of funding provided by ARENA and TasNetworks, and the networking across the partner organisations and externally to the pilot. These aspects of SNM and network governance are closely aligned and bring the dual lenses of the STS scholarship and the policy scholarship in parallel.

8.2.2 Chapter Five findings in relation to prosumers and utility policy

The paper forming Chapter Five 'The precursors of acceptance for a prosumer-led transition to a future smart grid' investigated how factors of engagement, agency, complexity and trust were related as precursors to technology acceptance. The research question for this chapter was '*What are the conditions that lead to consumer acceptance of a new technology?*' Technology acceptance by prosumers is critical for implementation and therefore upscaling, so directly relates to the theoretical basis of the thesis.

A key finding concerned the relationship between information, knowledge and agency. The Bruny Island participants held diverse views on the level of agency. Many participants desired more information on the battery technology, some were confident in their understanding, and others felt frustrated by a lack of agency. This finding of diverse agency requirements was coupled with system complexity and the problem of how the network (TasNetworks) could — feasibly and realistically — manage high levels of agency, given 'we [TasNetworks] cannot continue to provide a "Bruny level of service" to 10,000 batteries' (Jones, 2017, paraphrased). The paper argued that an interaction between the elements of agency, trust, engagement and acceptance were interlinked, and that these factors might be employed as a process to help industry better understand and manage energy prosumers. This was argued to occur by initially offering greater engagement/knowledge, but reduce complexity by allowing prosumers to trust the network, for example, in the form of a customised energy management plan, which would be expected to lead to greater levels of acceptance of the new technology.

The interlinked factors that may lead to technology acceptance of smart batteries by prosumers are summarised below in Figures 8.1.

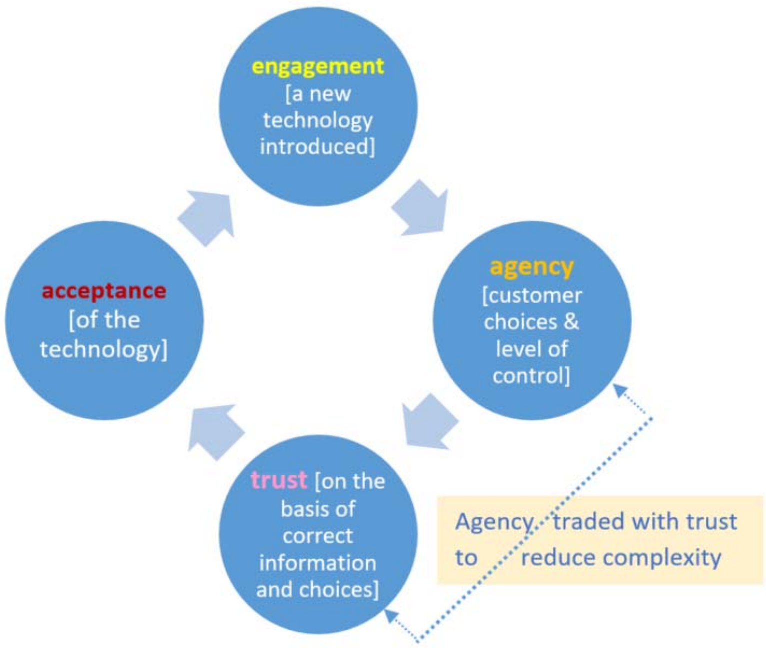


Figure 8.1 Process of technology acceptance, with an agency and trust equilibrium.

The paper suggested that energy industry actors and government may enhance technology acceptance and encourage policy and technology implementation by considering a process that applies engagement, agency, trust and acceptance, as shown in the figure above.

8.2.3 Chapter Six findings in relation to policy implementation

The paper that forms Chapter Six on the installers was titled 'The evolving role of battery system installers within a transitioning electricity sector'. *The paper aimed to examine how innovation intermediary roles might adapt post-disruption.*

The role of the installers as intermediaries and as emergent SLBs is argued to be critical for a system transition because of their implementation role, and to date in Australia the lack of an established way of implementing distributed storage technologies. In terms of the conceptual framing of intermediaries and SLBs, it was argued that the intermediaries are conceptualised within STS scholarship as innovative catalysts for change within a disruptive environment; conversely, SLBs were found to be stable and knowledgeable on their roles, with no specific requirement for being innovative because their main function is to competently perform well-known tasks. It was discovered for the CONSORT pilot that the installers were pivotal in the pilot's success, that a successful transition relies on installer knowledge, and that they undertake a heavy business risk as they are entering relatively new territory in the energy market.

It was found that the installers took financial risks, incurring additional costs (sometimes compliance costs, but often in labour hours). Another key installer-centric implementation finding was that the installers were found to have to engage, educate and empower prosumers significantly more than anticipated for 'consumer acceptance' of the new technology (the smart battery). However, where installers were found to offer more agency to their customer than desired for network control, unwittingly, the outcome was sometimes counterproductive for both the participant and for TasNetworks. Fundamentally, the installers, are *not yet* well equipped to deal with the new demands of software integration (which makes the 'smart' battery IoT intelligent), making it a significantly more complex system to install than current batteries with PV inverters.

In summary, applying the SLB scholarship to understanding innovation intermediaries allowed a possible future insight into the electricity system, post-disruption. It was found that installers, as potential SLBs, are not currently operating in a system with sufficient stability to accelerate an orderly transition. The figure below (8.2) was designed for Chapter Six to demonstrate these concepts and is provided again for reference:

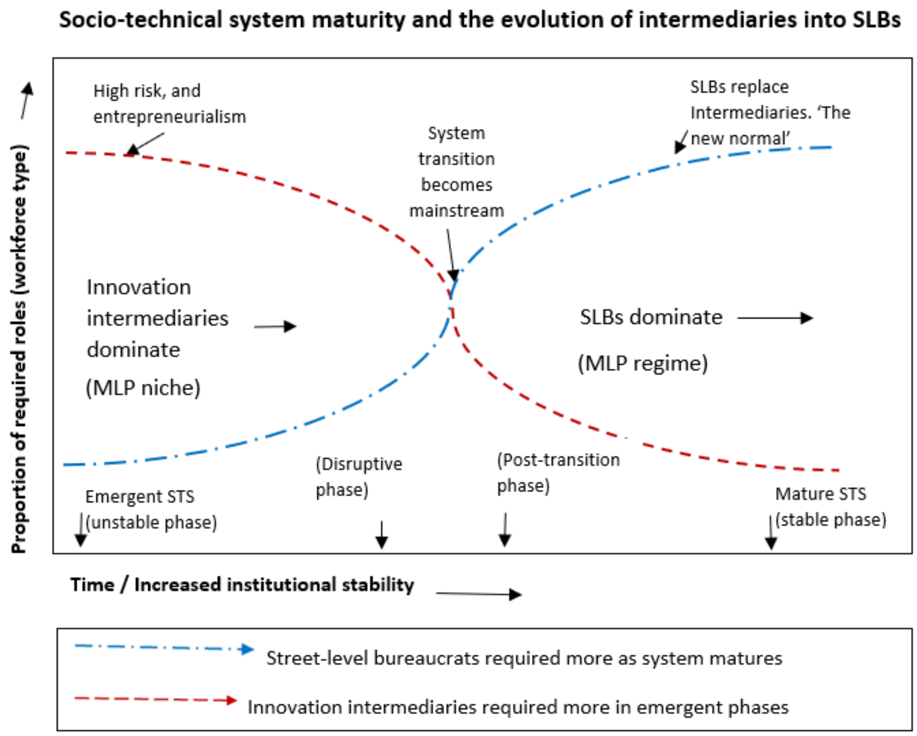


Figure 8.2 Social-technical system maturity and the evolution of intermediaries into SLBs

8.2.4 Chapter Seven findings in relation to prosumers

This study discovered that although cost considerations are significant in prosumer decision-making about battery-PV systems, other non-economic values were also significant. The dominant framing and discussion of the rationale for decision-making about residential batteries, in industry and government, is economic.

The exploration of the methodology of cost-benefit analysis as a decision-making tool was undertaken in relation to smart-batteries, and the research asked: *Are PV-battery systems cost-effective*? While also conducting an examination of the CBA assumptions, namely '*What are the CBA assumptions?'*

The calculation and outcome of the CBA for the participant BT112 was economically favourable, *only* with the significant subsidy. In terms of the underpinning *assumptions* of the CBA — these were significant, and it was argued that the categories of CBA-assumptions were divided into five types; 1) calculative 2) pace of technological innovation 3) warranty timeframes 4) feed-in-tariffs and 5) the value of reliability in the Bruny Island context.

In summary, whilst it was acknowledged that decreasing battery system costs would help drive the prosumer-lead electricity grid transformation, it is argued that understanding potential prosumers is even more significant. Prosumer preferences, consumer behaviour as well as non-economic decision-making are central to system change, though this does not seem to be fully grasped within government and industry reports. It is argued that government could intervene to encourage transition in an orderly manner, and it was suggested that smart batteries in rural (and edge of grid) contexts might be considered differently to urban contexts for equity.

8.3 The theoretical framework for enabling conditions for innovation breakthrough

The systems-thinking approach described by Hughes (1983) and adopted in this thesis is whole-of-system thinking and approach, which can support system change. The multiple-level perspective (MLP) description of large-scale change was investigated as part of the theoretical basis of the thesis within Chapter Two, and a modified MLP framework was devised for Bruny Island. This described the pilot as a technological niche, not at the fringes (as niches are normally described) but positioned with federal government support and support by an incumbent network utility within the regime, so that the pilot was conceptually sited within the regime. The significance of a supportive regime is indicative of a willingness by incumbents to adapt to radical change. The CONSORT niche-level pilot was viewed as straddling the niche and mainstream in terms of features and conditions, and this was described as an extension to the classical MLP framework.

Both the STS and policy literature contribute to an understanding of how new systems might be 'upscaled', with four pre-conditions presented as novel contributions to scholarship, as presented in Schematics A-D. It is suggested that the first two may be applied to projects, governments or utilities, and the second two were to a large extent uncontrollable by government policy.

The four insights related to pre-conditions or precursors of niche technologies that could lead to upscaling, or a breakthrough and system change, are described as part of the theoretical basis of the thesis (Chapter Two) and are presented again below as original work to compare against the empirical findings from the CONSORT case study.

A finding from Chapter Four described earlier was that the SNM activities of a protected niche (ARENA funding in particular, with support by an incumbent utility unlike most niche innovations), networking, knowledge-sharing and diffusion were found to exist within the CONSORT pilot. Figure 8.3A below illustrates a combined management approach (SNM) within niche projects and between niche projects; and a wider systems-thinking approach as per Hughes (1983).

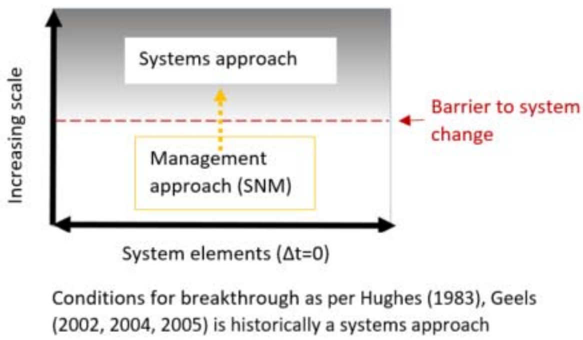


Figure8.3A. SNM and Systems Thinking as precursors for breakthrough to the mainstream, Schematic A

Figure 8.3B below represents the implementation of backward mapping (policy implementation) and network governance in order to influence the policy and regulatory environment.

Findings from the paper forming Chapter Six reflect the effect of upscaling related to policy implementation practices. SLBs exhibit backward-mapping policy implementation as part of their proximity to the point at which implementation occurs. Coherent, well-governed and managed implementation at the industry level and the lowest point of implementation is expected to significantly enhance the prospects of implementation success. Installers, as the closest point of implementation between the system and the prosumer were argued to be intermediaries, as early-stage SLBs that enhance an accelerated transition while maintaining orderly governance. Aspects of network governance were discussed in Chapter Four and this occurs more widely with learning by installers and the industry as examined in Chapter Six.

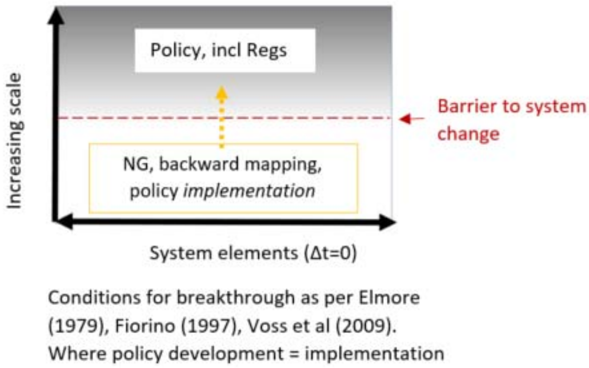


Figure 8.3B. Network governance and backward-mapping as precursors to breakthrough to the mainstream, Schematic B

Figure 8.3C below is illustrative of prosumer preferences driving transition, and indeed, all chapters throughout the thesis relate to citizens/prosumers as drivers of change. Chapter Five concentrates on the precursors of technology acceptance, with citizens and prosumers centrally placed as agents of change based on their acceptance of a new technology, or not. Similarly, Chapter Six concentrates on prosumers, but through the interaction they have with the installers as implementers of policy. Chapter Seven, likewise, concentrates on prosumers and uses a case study of one householder participant to explore decision-making typologies and cost-effectiveness and other values as factors that influence a prosumer-led transition.

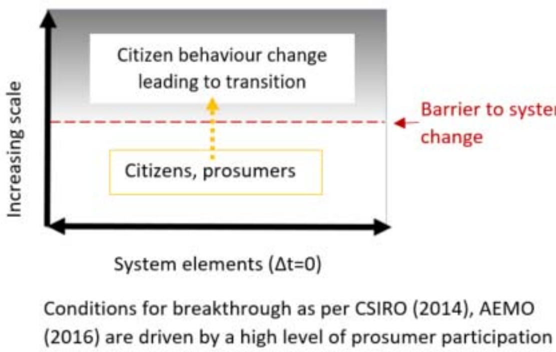


Figure 8.3C. Prosumer preferences drive change, lead to breakthrough to the mainstream, Schematic C

Figure 8.3D below recognises that new entrants and new business models may solve challenges for storage management. The schematic of Figure 8.3D highlights cross-cutting themes of the thesis. New-entrant small businesses, with Reposit as the example, interacted with SNM practices across the CONSORT wider team, as documented in Chapter Four (SNM). The findings of Chapter Five indicate a new space for new entrants if the incumbents are not able to fulfil it – namely, managing the prosumer relationships, new nimble ways of engagement and new models of business that may enhance technology acceptance. In the paper at Chapter Six, the interaction between the installers was discussed: the installers carry out the work onsite with the customer or prosumer, the new entrant does not. This can be described as an example of emergent network governance in the sector between two forms of new entrants — the installer firms and the ICT/IoT software firms.

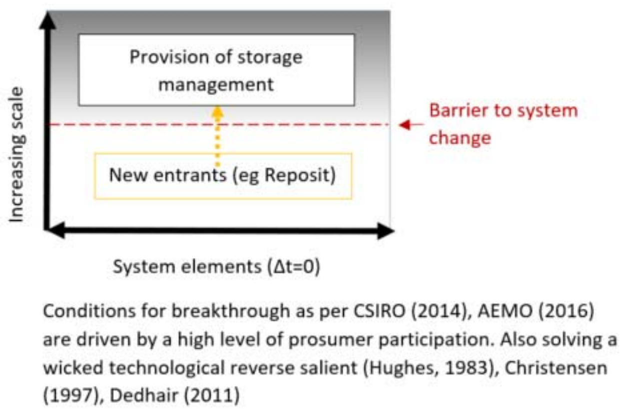


Figure 8.3D. New entrants to the energy system (and radical business models that include prosumers) lead to radical breakthrough to the mainstream, Schematic D

8.4 Conclusion

This doctoral research is about a critical contemporary problem: how a sustainable socio-technical transition might be accelerated. The thesis investigated how a transition for the residential energy sector might occur, focusing on a conceptual boundary between the niche and regime level of implementation. The insights of the pre-conditions of innovative breakthrough as described by the Figures 8.3A-D constitute four aspects that drive change at the niche-regime transition for residential batteries; that include ideas and concepts from the scholarship of SNM, STS, MLP, policy implementation and SLB scholarship with in depth empirical research of the CONSORT pilot as well as of the non-scholarly grey literature of government and industry reports.

In terms of prosumer agency, engagement and participation within the energy system, it appears that electricity sector disruption may both empower and burden consumers and disempower and burden utilities. The disruption is the energy trilemma, in terms of cost, reliability, and emissions; but it is also a dilemma in governance, in the shift of responsibilities for the systems behind the meter and the management of increasing complexity of the systems as the 'Internet of Things' is introduced. The overall findings of this thesis related to the prosumer-utility relationship during the transition. The pivotal importance of the installers was discovered, the economic value of battery systems to households, but also the non-economic values and other modes of decision-making were highlighted. The key practices of SNM to upscale innovative technologies were found to exist within the CONSORT pilot through: alignment of objectives; a protected learning niche where the inefficiencies of learning were tolerated; and networking and diffusion of knowledge. Such SNM practices are more relevant and applicable than ever as the energy system incorporates an 'Internet of Things' approach with increasingly 'virtual' connectivity. Virtual portals have increasing *pivotal relevance* for knowledge diffusion, whereas in 2006 when the most well-known SNM government policy document was written (Mourik & Raven, 2006) these formats did not exist. Importantly, it was found that the installers, as key implementation agents, were not included in SNM processes and decision-making within CONSORT; the consideration of installers as the implementers (innovation intermediaries and SLBs) is argued to be of critical importance to implementation success (for a pilot or more widely).

Analysis of the installers helped to demonstrate a link between the policy implementation scholarship and STS scholarship in a way that might reasonably be applied to understand a future trajectory of current installers as innovation intermediaries as potential, stable SLBs.

The interaction between the prosumers and the installers represents the point of interaction between a citizen and the energy system. The values and preferences of the prosumer are critical to the shape of the future energy system and rate of transition and these include non-economic values. Technology acceptance, as investigated through the precursor conditions of engagement, agency, and trust leading to acceptance, provide an idealised path for network utilities to manage prosumer preferences in an orderly manner, whilst encouraging an acceleration of the transition.

8.4.1 A highlight of original scholarly contributions

This thesis investigated how transitions occur, and what the favourable pre-conditions are for transition (or an innovative breakthrough to the mainstream). Insights on those pre-conditions were formed from a synthesis of two streams of scholarship.

Firstly, a model describing four pre-conditions for innovative breakthrough, as synthesised by the scholarship was presented, and was highlighted in Section 8.3 above. These pre-conditions or precursors for transition describe in detail specific factors from policy knowledge and STS, to extend MLP at the interface between niche to regime scale.

Secondly, the thesis extends the STS scholarship on the role of intermediaries — where a post-disruptive paradigm is put forward; and intermediaries are but emergent (policy) SLBs in the mature phase of the hybridised electricity system.

Thirdly, a new and dynamic process to assist in technological acceptance for industry use was developed in Chapter Five. The process focuses on the exchange between prosumer agency, complexity, and trust, and this process of initial high engagement was outlined.

Fourthly, in terms of a novel approach, this thesis examined strategic niche management (SNM) in relation to the CONSORT pilot, as a contemporary, live, smart grid pilot, and not as the predominant literature in the field, on *exe post* studies, or studies of the electric vehicle niche. The novel contribution to scholarship here is that the SNM scholarship is applied for the first time within the pilot itself as it unfolds and conceptually tested with the project researchers and policy experts. The 'real time' application revealed small-scale SNM practices that occurred within the project teams, and not just externally.

This thesis presented a novel focus on the area of scholarship on policy implementation, which is under-researched by comparison to policy development. Often an unintended 'implementation gap' occurs where the 'plan' and the 'outcome' are not met successfully. Specifically, an original contribution in re-imagining ways to close the implementation gap through the support and frameworks that could be provided for the installers to facilitate a more orderly transition.

The study of a socio-technical pilot *through a policy implementation lens* is an original approach. Understanding implementation is critical to understanding what may enhance implementation success. As described in Chapter Two, the study of policy implementation remains a useful and under-researched area. In the paper at Chapter Six, the concept of 'leaving the implementation to the administrators' in the governmental sense refers to the installers who are 'left' to trouble-shoot the policy outcomes in a highly complex and uncertain reality. Policy implementation in terms of institutionalising SNM was evidenced through Chapter Four. Policy implementation — through the perspective of the incumbent utility policy and prosumer was evidenced in Chapter Five, where it was suggested that utilities need to offer engagement, knowledge, variable levels of (smart battery) agency in order to win trust and optimise the future grid.

8.4.2 Broader relevance of the study

Broader relevance of the findings can be established and is evidenced by the following —

- Technology acceptance as studied in Chapter Five on the themes of engagement, agency and trust in this thesis are broadly transferable to other innovative technologies.
- Installers of technologies, the face to face knowledge brokers are more pivotal to transition than previously realised.
- The pre-conditions for innovative breakthrough A) SNM, B) backward mapping C) Prosumer preferences and D) new entrants or models solving the big challenges – that the most direct to manage and influence are A,B (both relate to management and policy within projects and between projects and institutions) Pre-conditions C and D are not controllable – though can be influenced to a limited extent. For example, for C – government subsidized for batteries would lead to increased prosumer uptake of the systems and this might have a social trickle-on effect. For D, new entrants are expected to appear where challenges present themselves to the incumbents. An incumbent such as TasNetworks can be seen as future-proofing or shielding their business-models by investing significantly into projects such as CONSORT where they are partnering with a new entrant.
- The 'ideal' of the democratisation of energy implies great agency, participation and control. This may not be in the prosumer or network best interests or even desirable beyond an abstract principal to practical reality because the control of electricity is mundane and is something that has required little thought from most consumers / householders for many decades.
- The project ethnography chapter demonstrated SNM practices that could be transferred to other projects to some extent and that the findings derived from interdisciplinary research is greater than the sum of the parts
- Prosumers will drive change, and cost is a very significant factor, but it is not the only factor – this is transferable to all new innovative sustainable technologies.
- Backward-mapping policies that consult with stakeholders and consumers as well as focussing on the lowest point of behaviour that calls for policy and stepping back from there – are likely to yield more successful results.

The practical applications and implications include —

- There are implications for how utilities as policy influencers can manage agency. For policies that enhance and support the installer role.

- Agency and engagement - What was found here is that power companies and networks have an opportunity to once again tame and manage the complexity of prosumers by making basic decisions of trading and electricity supply for them, as agreed and understood by the prosumer.

8.4.3 Final conclusions and recommendations for future research

In terms of prosumer agency, engagement, and participation within the energy system, it appears that the electricity sector disruption may both empower and burden consumers; and disempower and burden utilities. The disruption is the energy trilemma, in terms of cost, reliability and emissions, but also a dilemma in governance; in the shift of responsibilities for the systems behind the meter and the management of increasing complexity of the systems as the internet of things is introduced.

The overall findings of this thesis related to the prosumer-utility relationship during the transition. The pivotal importance of the installers was discovered, the economic value of battery systems to households, but also the non-economic values and other modes of decision making were highlighted. The key practises of SNM to upscale innovative technologies, were found to exist within the CONSORT project; through alignment of objectives, through a protected learning niche where the inefficiencies of learning were tolerated; and networking and diffusion of knowledge. In addition, these factors are more relevant and applicable than ever as the energy system incorporates an ‘internet of things’ approach with increasingly ‘virtual’ connectivity. Virtual portals have increasing *pivotal relevance* for knowledge diffusion whereas in 2006 when the most well-known SNM government policy document was written (Mourik & Raven, 2006) these formats did not exist.

To answer the question: *‘During a time of systemic disruption within the electricity sector in Australia, how might smart grids be encouraged to be accelerated and governed in an orderly manner?’*

This answer can be encapsulated as government providing policy and regulatory support for both new entrants, as well as incumbent utilities with new business models. In future, SNM practices could be institutionalised (innovation hubs are an example), whereby stakeholders engage in a networked governance manner — where industry, academia and the energy industry (and particularly start-ups) are encouraged to adopt an SNM-like model and might be housed under ARENA (or similar).

It is hoped that, in this time of disruption — where agency is increasing for prosumers (due to distributed, privately owned storage), that governance responsibilities might also become more distributed (networked), so that VPPs within the NEM might operate in a fair, orderly and efficient way. Distributed energy storage remains highly complex for prosumers and a future key challenge for utilities is reducing that complexity, through agency and trust.

Appendices

The appendices comprise two parts.

Appendix A includes the UTAS Ethics H0016022 (PhD) information including indicative question sheet templates for the PhD-specific questions. Interview questions for the social science Ethics H0015883 are not included here as they were not PhD-specific as they were team contributions. Appendix A also includes the thesis interview data (tabulated), and a list of documents and communications both publicly available and internal to the project.

Appendix B lists candidature outputs provides an example (IEEE publication), as well as the PhD contribution to ARENA Milestone Reports.

Appendix A — Ethics H0016022 application, amendment and final report; consent form, information sheets and question templates.

This appendix contains information relating to the PhD Ethics Application H0016022. Documents comprise:

1) The Minimum Risk Application [approved].
2) An approved amendment to H0016022 to include 'shadowing' of installers.
3) Information sheet.
4) Consent forms [a general consent form and an installer-specific consent form].
5) Indicative questions [indicative questions for a] policy and regulators; b) researchers; c) utility and networks; and, d) installers]
6) Minimum Risk Application Final report H0016022

HUMAN RESEARCH ETHICS COMMITTEE

(TASMANIA) NETWORK

SOCIAL SCIENCE HREC
MINIMAL RISK APPLICATION

Important: Please send an electronic version of this form as a Word document along with all attachments to katherine.shaw@utas.edu.au.
A signed copy of this form also needs to be forwarded electronically.

If you have any questions, please call: 6226 2763

1. Title of proposed investigation
Please be concise but specific. Titles should be consistent with those used on any external funding application. **ARENA CONSORT Smart Grid Pilot: Governance, implementation and the utility-community relationship.**

2. Expected commencement date:	**Expected completion date of project**
06-07-16	06-07-19

3. Investigators:

A. Chief Investigator (Note: This is the researcher with ultimate responsibility for the project. The CI may not be a student)

Given Name	**Surname**
Heather	Lovell

Staff Position: Australian Research Council Future Fellowship (2015-2018). **Qualifications:** Associate Professor

Staff ID: 0.......

School & Division: School of Social Sciences

Contact Address:	Room 405, Social Sciences Building, Sandy Bay Campus, University of Tasmania.		
Telephone:	(03) 6226 7243	**Email:**	heather.lovell@utas.edu.au (Required)

B. Co-Investigator(s)

i) Given Name	**Surname**
Phillipa	Watson

Staff Position:	Research Fellow	**Qualifications: PhD**	
Staff ID:	0…….		
Contact Address:	Room 407, Social Sciences Building, Sandy Bay Campus, University of Tasmania.		
Telephone:	(03)62267228	**Email:**	phillipa.watson@utas.edu.au (Required)

ii) Given Name	**Surname**
Katherine	**Crowley**

Staff Position:	Deputy Head, Social Sciences	**Qualifications:**	Associate Professor
Staff ID:			
Contact Address:	Lvl 5, Social Sciences Building, Sandy Bay Campus, UTAS		
Telephone:	(03) 6226 2364	**Email:**	Kate.Crowley@utas.edu.au (Required)

C. Student Investigator(s):

i) Given Name	**Surname**
Veryan	Hann

Gender: female **Date of Birth:** ..-..-.. **Preferred Title:** Mr / **Ms** / Miss /Mrs /Dr

Student Number: 9.....

Level: Undergraduate / Hons / Masters / Postgraduate Diploma / **PhD**

School: School of Social Sciences

Contact Address: ...., TAS, 7008

Telephone:	0428973700	**Email:**	veryan.hann@utas.edu.au (Required)

ii) Given Name **Surname**

Gender: ________ **Date of Birth:** ____________ **Preferred Title:** Mr / Ms / Miss /Mrs /Dr

Student Number: ____________ **Level**: Undergraduate / Hons / Masters / Postgraduate Diploma / PhD

School: ____________

Contact Address: ____________

Telephone: ____________ **Email:** ____________ (Required)

D. Conflicts of Interest

Do any of the researchers have a conflict of interest, or what could be perceived as a conflict of interest? (NS 5.4) Yes ☐ No ☒

A conflict of interest in the context of research exists where:

- *a person's individual interests or responsibilities have the potential to influence the carrying out of his or her institutional role or professional obligations in research; or*
- *an institution's interests or responsibilities have the potential to influence the carrying out of its research obligations.*

A perception that a conflict of interest exists can be as serious as an actual conflict.

If YES – please provide details:

Please describe the nature of the conflict.

Please describe how the conflict will be managed.

4. Purpose			
What is the main purpose of this project?			
Research for Publication	☐	Teaching	☐
Research for Thesis	☒	Quality Assurance/Audit	☐

5. Brief Outline of Proposal

Aims:

The PhD study will examine the CONSORT electricity pilot; and the overall aim is to further the understanding of the dynamics between the network, householder and governance structures (including policy*). To understand this, is to understand the future of the grid*: in terms of trends, and the regulatory and social feasibility of policy implementation of smart grids.

Research questions of the PhD study may include:

Questions of the system relationships:

- What can be learnt from the CONSORT smart grid pilot as a case study, which can be of benefit to the householders-network-governance dynamic; and of a broader societal benefit of the perspective of policy implementation?
- What are the implications of Australian regulations on the area of socio-technical innovation, and especially, in relation to successful implementation (or otherwise) of this trial?

Community related questions:

- Policy implementation, to be successful, requires acceptance by the community; so given the circumstances of the pilot, can something be learnt about the conditions for householders to accept new technologies and ways of behaving/living?
- How can the utility and the regulators learn from community responses?

Regulatory, governance and policy questions:

- How do the regulators (governance structures) keep up with this speed of change and innovation? How can the regulators assist the distributed network, and the householder?
- How can regulation and policy enhance the utility- prosumer relationship? (A 'prosumer' is *both* a 'producer' and 'consumer' of electricity).
- A growth in prosumers in Australia reflects increasing renewable energy into the grid; as well as increasing consumer participation/ownership and encouraging transparent management of energy use and generation; in addition to supporting network infrastructure. How could this be managed and enhanced?

Justification:

Explain why this particular study is worth doing; and the main advantages to be gained from it.

The premise of the PhD study is that Smart Grids are a significant and emergent part of Australia's future energy system and that it is critical to understand consumer-utility-regulatory interactions in order to build policy which is fit for purpose into the future.

The energy system is currently experiencing a 'disruption' and structural transformation; this is partly due to increased decentralisation with small scale renewable energy (residential solar PV).

Unravelling the complexities of the evolving relationships between the consumer-utility-regulatory landscape also requires understanding the consumer or community responses to innovative technology. It involves understanding what barriers and opportunities exist for policy implementation what affects the community in optimal ways.

Further, understanding how utilities are responding in the current time of flux and how they may be responding with changing business models which interact with the spheres of community and government are also important to investigate as they provide indicators to the future of the grid.

The PhD study sits under a larger pilot project (CONSORT) which is multi-disciplinary and engages five partner organisations; it is focussed on a practical solution to network limitations, and the project combines industry, academia and the community in this research.

Veryan's PhD candidature is the only PhD within the CONSORT project that is investigating the pilot from a *social sciences* perspective; the other candidates involved are focussing on technical (engineering and software) aspects of the trial. Understanding how the project pilot unfolds from a social sciences viewpoint is important as there are significant instances where technological or engineering know-how exist, and yet there is policy implementation failure. In this instance, the social research allows a window to understanding the technology's impact on people. With heavy investment into research and development into increasing renewable energy within the electricity grid occurring in Australia, and overseas, it is important to understand how policy can either act as a barrier or drive network innovation. It is also important to understand how energy consumers; and for this pilot, a range of householders in particular, interact with new technologies; it is important to understand the spectrum of response in order to appropriately and optimally address this.

For this trial, householder responses may help shape ideas on future grid implementation pathways. Household behaviour is studied through CONSORT UTAS team and this data will also be used by the PhD candidate for her research. The overall picture is understanding the relationship between the prosumers [consumers that generate small scale electricity] and the networks. The network and prosumer relationship is at the heart of the future of a viable energy system - it is not yet known what form this will take – this CONSORT project is a test bed of how this interaction could be designed to be mutually beneficial. The University of Tasmania Team will be investigating these areas.

The PhD candidate will also be investigating these areas with greater focus and depth on the interfaces of policy implementation and the smart grid pilot as the case study; and theory of sociotechnical change and the relationship of people and a changing system and technology. These four areas outline the CONSORT project objectives as well as overlapping with the PhD objectives which will be pushing at the policy implementation and social science praxis in a transforming energy system.

Other reasons for the study's use is the applicability to other jurisdictions around Australia, or indeed globally if the pilot is successful. Regardless of the practicalities of perceived levels of success or otherwise, the CONSORT project will be instructive and will provide understanding and learnings to future endeavours.

6. Review of Ethical Considerations *Research is only considered to be Minimal Risk if you answer "No" to all the following questions. If you answer "Yes", you must complete a full application using the Social Sciences Full Application Form*	
Does your research involve the collection of human tissue samples? Human tissue samples include blood and other bodily fluids.	Yes ☐ No ☒
Does your research involve the deception of participants, including concealing the purposes of research, covert observation and/or audio or visual recording without consent?	Yes ☐ No ☒
Does your research involve the participation of people without their prior consent?	Yes ☐ No ☒
Does your research involve withholding from one group specific treatments or methods of learning from which they may benefit?	Yes ☐ No ☒
Does your research involve the access or use of medical records where participants can be identified or linked to their records in some way?	Yes ☐ No ☒
Does your research involve the use of ionising radiation?	Yes ☐ No ☒
Does your research involve the use of personal data obtained from a Commonwealth or State Government Department/Agency without the consent of the participants e.g. getting a list of addresses from the Australian Electoral Commission?	Yes ☐ No ☒
Does your research **specifically target** any of the following groups of people; (specifically target means they are the central group of participants, as opposed to potentially being incidentally recruited as part of the general population) • Women who are pregnant and the human foetus • Children and young people • Those highly dependent on medical care who are unable to give consent • People with a cognitive impairment, intellectual disability or mental illness • People who may be involved in illegal activities or residents of custodial institutions • Aboriginal and Torres Strait Islander Peoples • People in other countries	Yes ☐ No ☒

• People who are unable to give informed consent because of difficulties in understanding an information sheet (i.e. non English speakers etc)	
Does your research pose any risks for participants under medical care beyond those of their routine care? (Risks include not only physical risks but also psychological, spiritual and social harm or distress eg stigmatisation or discrimination)	Yes ☐ No ☒
Does your research involve the in depth discussion of any of the following topics whether by interview or as part of a questionnaire or survey; • Parenting practices, • Sensitive personal issues, • Sensitive cultural issues, • Grief death or serious traumatic loss, • Depression mood states or anxiety, • Gambling, • Eating disorders, • Illicit drug taking or substance abuse, • Psychological disorders, • Suicide, • Gender identity and/or sexuality, • Race and/or ethnic identity, • Fertility and/or termination of pregnancy	Yes ☐ No ☒
Does your research involve the potential disclosure of illegal activities or criminal behaviour?	Yes ☐ No ☒
Are there any specific risks to the researcher (e.g., will the research involve the use of hazardous materials or be undertaken in a politically unstable area)?	Yes ☐ No ☒
If your research will take place in an overseas setting do any of the following apply: is the research to be undertaken in a politically unstable area? Does it involve sensitive cultural issues? And/or: will the research take place in a country in which criticism of the government and institutions might put participants and/or researchers at risk?	Yes ☐ No ☒
Does your research explore potentially confidential business practices or seek to elicit potentially confidential commercial information from participants?	Yes ☐ No ☒

Does your research explore potentially divergent political views or involve the collection of politically sensitive information?	Yes ☐ No ☒

7. Funding

Under the National Statement (2.2.6) a researcher must disclose:

- *the amount and sources or potential sources of funding for the research; and*
- *financial or other relevant declarations of interest of researchers, sponsors or institutions*

Is this research being funded? Yes ☒ No ☐

If yes, please detail amount and source of funds (NS 5.2.7)	The amount of funding for the PhD Candidate is a living allowance stipend of approximately $26,288pa for 3 years.
If this application relates to Grant(s) and/or Consultancies, please indicate the Title and Grant Number relating to it	This funding sits under grant number: Research Office project number is T23534

If no external funding has been obtained, please indicate how any costs of research will be met:

Do the investigators have any financial interest in this project? *If yes*, please provide details	Yes ☐ No ☒

8. Participants

Selection of Participants

Clearly describe the experimental and, where relevant, control groups. Include details of number of subjects, sex, age range, and any special characteristics. Give a justification for your choice of participant group(s).

The ARENA Smart Grid Pilot recruited participants through TasNetworks (externally) and this was approved under the Ethics Application for project H15886. Therefore, the households that participate in the trail are selected by an external agency. In addition, TasNetworks has contracted Solar PV installers so that there are 7 installer brands that the participants can choose from. I would also seek interviews with the installers as they are a critical interface with the technology; it's physical implementation; and the householders experiencing the new technology. Further, I would also seek to interview other suitably qualified experts (in the order of 6 in total is envisaged) in energy policy implementation and/or in the regulatory environment to understand the constellation of actors which make up this energy ecosystem; and how it could be optimised for the future. Selection of interview participants would be sought from The Australian Energy Regulator (AER), and policy and regulatory representatives from the Australian Energy Market Operator (AEMO) and the Australian Energy Market Commission (AEMC), and the Australian Renewable Energy Agency (ARENA). In addition, it may also be valuable to have the opportunity to also interview other members of the CONSORT team, who are experts in the field of solar PV technology and other areas that are critical to the success of this pilot study; however, this will be assessed by the end of 2017 and interviewees would be contacted via email to be invited for interview. Age, sex or any personal characteristics outside of expert professional knowledge; or in the case of how householders respond to the technology is not relevant for this research.

Recruitment of Participants

Give specific details about how participants will be recruited. Some questions to consider include:

- *Are you recruiting through advertisements? If so, indicate where they will be placed and append a copy*
- *Are you recruiting through 3rd parties like associations, schools or clubs? If so, detail how you will approach the organisations and the process that the stakeholders will use to pass on information to potential participants. Please attach copies of letters of introduction, emails, and telephone preambles if appropriate*
- *Are the participants University or DHHS staff, or regular patients in a particular clinic? If so, detail how they will be approached i.e. through personal invitation, email etc*

TasNetworks is recruiting householders as participants for this study; they are pre-selected for the trial for technical compliance reasons related to the Smart Grid operation. For interviews with energy experts; these participants are either already known to the researcher or will be requested to interview through other channels; for example, I would be meeting installers in the field as part of the fieldwork (on Bruny Island) and I would ask them in person if they would be willing to participate in my research, I would then later interview (no more than 3) in Hobart, or over the phone at their convenience. For other experts, I would likely contact these individuals directly by email because of their role (e.g. they work at the Australian Energy Regulator in devising policy) and then if they are positive towards the concept of interview, I would then email them the Information Sheet, Consent Form and follow up with questions via email or phone; depending on the interviewees preference.

9. Data Identifiability

Which of the following best describes the identifiability of the data (including tissues) collected?

a) Non-identifiable data is data which have never been labelled with individual identifiers or from which identifiers have been permanently removed, and by means of which no specific individual can be identified. A subset of non-identifiable data are those that can be linked with other data so it can be know that they are about the same data subject, but the person's identity remains unknown.	☐
b) Re-Identifiable data is data from which identifiers have been removed and replaced by a code, but it remains possible to re-identify a specific individual by, for example, using the code or linking different data sets	☒
c) Identifiable data is data where the identity of a specific individual can reasonable be ascertained. Examples of identifiers include the individuals name, image, date of birth or address, positions in some companies.	☐

If the information is Re-Identifiable or Identifiable, please give details of the information that will be collected. Also indicate how the confidentiality and anonymity of the participants will be protected:

The majority of the participants are the householders on Bruny Island, and Ethics with this cohort has been dealt with under Ethics H15886. For the supplementary PhD interviewees, the information of the following will be collected: Full Name; Role of job title and/or description; Name of the organisation / government department they work for. Confidentiality and anonymity will be protected by providing a code [probably an alphabetical letter] for the interviewees and this information of the code and interviewee will be a document kept on a password protected university computer held under the candidate's possession until completion of the project. This document of identifiers will be deleted at the same time as all other documents as agreed within this Ethics application.

10. Relevant Literature References

Please list the most relevant and recent literature references, both by the investigator and/or by others, that support the justification for the study.

Governance and Technical

Australian Electricity Market Commission (2016). 'Five Minute Settlement'. Information /media release, AEMC, Senior Director responsible for the information, Chris Spangaro aemc@aemc.gov.au

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Sociotechnical and innovation theory

Bulkeley H, Powells G, and Bell S (2016). 'Smart grids and the constitution of solar electricity conduct'. *Environment and Planning* A 2016, Vol. 48(1) 7-23. DOI: 10.1177/0308518X15596748

Buscher C, and Sumpf P, (2015). "Trust" and confidence" as socio-technical problems in the transformation of energy systems'. *Energy, Sustainability and Society* (2015) 5:34 pp.13

Meadowcroft, J. (2009). "What about the politics? Sustainable development, transition management, and long term energy transitions." Policy Sciences 42(4): 323-340.

11. Procedures

Researchers should explain how the investigators intend to conduct the study including the methodological approach, the specific procedures employed and the methods of analysis of data. This should be consistent with the aims of the project.

Please provide detailed procedures (describe exactly what you are going to do):

The procedures of this study form two (2) parts; the first part falls under the greater UTAS CONSORT pilot procedures which are detailed under the approved H15886 Ethics application, and include the H15886 Attachment C which outlines Methods and Indicative Questions.

The second part forms additional questions in fulfilment of PhD study; this takes the form of semi-structured interviews by phone of Householders, which is a part of the existing schedule of 4 interviews under H15886, and other cohorts are separate interviews as these are not being conducted under H15886. The additional interviews would comprise (3) installers and also Regulatory or Energy Experts (6).

Indicative questions for this are outlined in the Indicative Question Sheet submitted as part of this application; and the data will be qualitatively analysed in reference to existing theory, and in the context as the smart grid as a case study. It is likely that the data and responses will be first divided into themes and the nature of responses analysed in relation to perceived strategic bias which could be qualified; and in a way that provides context without identification of any individual.

Where is this project to be conducted? Researchers should attach a letter of agreement/support to participate from any organisation or department whose resources will be accessed as part of this project.

The project interviews are conducted at the participants' households and by telephone as per H15886 approved protocols; this comprises the in-situ fieldwork.

Interviews by telephone with key energy experts and installers will also be conducted.

Desk based project study will be conducted from Hobart, on and off campus will make up the remainder.

12. Monitoring
What mechanisms do you intend to implement to monitor the conduct and progress of the research project? (*National Statement* 5.5) As per the hierarchy of the PhD sitting under the UTAS CONSORT Team, and this team sitting under the umbrella of the ARENA project, it has requirements, as per H15886. For the PhD study itself, there will be regular face-to-face meetings between the candidate and her supervisors, as well as frequent email contact between the candidate and her supervisors throughout the duration of the project. The progress of the candidature will also be measured online, and accessible to the supervisors within iGRad, which includes addition to and monitoring of the Research Plan and Milestones within iGRad.

13. Data
A. Collection, use or disclosure of personal information Does the proposed research involve the collection, use or disclosure of personal information held by a Commonwealth or State agency, or an organisation in the private sector? ☐ Yes If yes, please complete & submit the **Privacy Form** along with your application. ☒ No
B. Storage
All raw data (including blood and/or tissue) must be held by the responsible institution (i.e. UTAS, DHHS, AMC) for a period of at least five (5) years from the date of the first publication (this includes publication of the thesis). The data may be kept for longer than five (5) years but must eventually be destroyed, unless explicit consent is obtained from the participants to archive their data. Where will the data be kept? The data related to the PhD work will be kept on a password protected University of Tasmania computer in possession of the candidate. How will the data be kept secure? The data will be kept on a password protected, University of Tasmania computer in possession of the candidate. The raw data for the CONSORT project is kept on UTAS computer and UTAS servers on campus, and in a locked room if the room is unoccupied for any length of time. For the lower level PhD work) under the CONSORT umbrella), PhD related interviews with installers or energy policy experts and so forth will also be on a UTAS password protected computer, and is likely that some of the data will also be on the UTAS server and the door to the office shall be locked when unattended for any length of time.

How and when will the data be destroyed? The information will be kept for 5 years after the completion of the pilot project, then deleted securely, with any paper data shredded.

14. Consent	
Chapter 2.2 of the *National Statement* provides guidelines on the requirements for consent in human research. With few exceptions, participation must be voluntary and based on sufficient information and an adequate understanding of the proposed research. In general, an information sheet and consent form is used to provide potential participants with necessary information about study and to obtain their consent should they choose to participate.	
Does the research involve:	
☐	An opt-out approach (Section 2.3.5 of the *National Statement*). Please complete section 14A below.
☐	A waiver of consent (*National Statement* 2.3.10). Please complete 14B below.
☒	Obtaining consent from participants prior to their involvement or to the use of their data. Please complete section 14C below.

14A Opt-out approach
Why is explicit consent neither practical nor feasible? (*National Statement* 2.3.5)
How does the public interest in the proposed activity substantially outweigh the public interest in the protection of privacy? (*National Statement* 2.3.6(b))
Why is it crucial that your data be as near-complete as possible? (*National Statement* 2.3.6(c))
Provide details on the information provided to the participants including the nature of the data to be collected, the purpose for collecting it, and the procedure to decline participation or withdraw (*National Statement* 2.3.6 (d)).
How much time has been allowed between the participant receiving information and the use of the data? (*National Statement* 2.3.6(e))
What mechanism(s) are there for participants to obtain further information and register for non-participation? (*National Statement* 2.3.6(f))

Provide details on the governance process in place. Including the process that delineates specific responsibility for the project and the appropriate management of the data in accordance with relevant security standards. (*National Statement* 2.3.6(g) and (h))

14B Waiver of Consent	
Why do the benefits of the research justify any risks of harm associated with not seeking consent? (*National Statement* 2.3.10(b))	
Why is it impracticable to obtain consent? (*National Statement* 2.3.10(c))	
Is there any reason for thinking that participants would not consent if they were asked? (*National Statement* 2.3.10(d))	
Will the results of the research have significance for the participants' welfare?	
☐ Yes	If yes, how will the information arising from the research be made available to the participants? (*National Statement* 2.3.10(g))
☐ No	
How will the participant's privacy be protected? (*National Statement* 2.3.10(e))	
Explain how confidentiality of participants and their data will be protected in the dissemination of research results? (*National Statement* 2.3.10(f))	

14C Information Sheet and Consent Form
How will potential participants be informed about the purpose, methods, demands, risks and potential benefits of the proposed research prior to deciding to participate? (please refer to 2.2.2 & 2.2.6 of the *National Statement* for a list of information to be communicated to participants) (*Information Sheet and Consent Form templates are available on our website at:* http://www.utas.edu.au/research-admin/research-integrity-and-ethics-unit-rieu/human-ethics/human-research-ethics-review-process/social-sciences-hrec/forms)
☒ Information Sheet – Please attach to the application
☐ Other – Please describe:
How will participants provide consent for participating in the proposed research?
☒ Consent Form – Please attach to the application
☐ Other – Please describe:

15. Approvals from other Departments / Institutions	
Does this project need the approval of any institution other than the University of Tasmania and/or the Department of Health and Human Services (e.g., Department of Education, particular wards in hospitals, prisons, government institutions, or businesses)? No ☒ Yes ☐ *If yes*, Please indicate below the Institutions involved and the status of the Approval. Name of Other Institution(s): Status:	
Does this project need the approval of any other HREC? *If yes*, Please indicate below which HREC and the status of the application.	No ☒ Yes ☐ (please detail): Other HREC(s): Status:

16. Declarations	
The Head of School or the Head of Department is required to sign the following statement of scientific merit: "This proposal has been considered and is sound with regard to its merit and methodology." The Head of School or Head of Department's signature on the application form indicates that he/she has read the application and confirms that it is sound with regard to: (i) educational and/or scientific merit and (ii) research design and methodology. This does not preclude the Committee from questioning the research merit or methodology of any proposed project. If the Head of School/Department is one of the investigators, this statement must be signed by an appropriate person. This may be the Head of School/Department in a related area or the Dean. The certification of scientific merit may not be given by an investigator on the project.	
Name	Catherine Palmer
Position	Head, School of Social Sciences
Signature	
Date	6.11.17

Conformity with NHMRC Guidelines The *Chief Investigator* is required to sign the following statement: I have read and understood the *National Statement on Ethical Conduct in Human Research 2007 and the Australian Code of Conduct for Responsible Research 2007.* I accept that I, as Chief Investigator, am responsible for ensuring that the investigation proposed in this form is conducted fully within the conditions laid down in the *National Statement* and any other conditions specified by the HREC.

Name of chief investigator	Associate Professor Heather Lovell
Signature	
Date	06-Sept-2016

Signatures of Other Investigators

I acknowledge my involvement in the project and I accept the role of the above researcher as chief investigator of this study.

(Name) Dr. Phillipa Watson (Name) Associate Professor Kate Crowley	(Name) (Signature)	(Date) 06-Sept-2016 (Date) 08-Sept-2016
(Name) Veryan	(Signature)	(Date) 06-Sept-2016

Checklist	
Please ensure that the following documents are included with your application:	
Information sheet/s (if not attached ensure you have explained why in Section 14)	☒
Consent form/s (if not attached ensure you have explained why in Section 14)	☒
Questionnaires (if applicable) N/A	☐
Interview questions (if applicable) [indicative]	☒
A copy of any permissions obtained i.e. Other HREC, Other Institutions (if applicable)	☐
Telephone Preambles (if applicable) N/A	☐
Recruitment Advertisements (if applicable) N/A	☐
Email Contents (if applicable) N/A	☐

All documents relevant to the study, including all information provided to participants	☐

Finance and Administration		
Fee Schedule as of 1 July 2013		
☒	Researchers affiliated with the University of Tasmania or the Department of Health and Human Services for the purposes of the research	No charge to the Researcher
☐	Minimal Risk Applications by External Researchers	$300
	Invoice Details	
	Name:	
	Organisation/University:	
	ABN Number:	
	Address:	
	Phone:	

To submit this application:

1. You must email an electronic copy of this application form (may be unsigned) and all study documents to Katherine.Shaw@utas.edu.au (please submit all forms as Microsoft Word documents).

2. A signed copy of this form also needs to be forwarded electronically.

Has the Head of School/Department signed the form? ☒

Have all investigators signed the form? ☒

Tasmania Explore the possibilities	HUMAN RESEARCH ETHICS COMMITTEE (TASMANIA) NETWORK	UTAS

SOCIAL SCIENCE HREC
AMENDMENT TO APPROVED PROJECT

This form should be completed to apply for amendments to all types of applications previously approved by the Social Science HREC.

Important: Please send an electronic version of this form as a Word document along with the attachments indicated below to katherine.shaw@utas.edu.au.
A signed copy of this form also needs to be forwarded electronically.

If you have any questions, please call: 6226 2763

Ethics Reference Number	**H016022**	**Date:**	1-Nov-2017

1. Title of approved project
ARENA CONSORT Smart Grid Pilot: Governance, implementation and the utility-community relationship.

2. Investigator names	
Chief Investigator	**Heather Lovell**
Phone:	**(03) 6226 7243**
Email:	**heather.lovell@utas.edu.au**
Other Investigator	**Veryan Hann**
Phone:	**(03) 6226 2339**
Email:	**veryan.hann@utas.edu.au**
Other Investigator	
Phone:	
Email:	

3. Requested changes to project

(These may include, for example, changes in procedure or direction of the project, changes to research personnel, changes in the source or manner of recruitment, or changes in the number of subjects.)

The change is to collect observational data from electrical contractor's work; in addition to an interview.

Note that the electrical contractors are not bound or obliged to provide this additional information, it is solely a request for additional data; which is collected while accompanying them on their work installing PV-battery systems; and they can choose to do this, or choose not to, for any reason.

The installers will be contacted for an interview as per original H016022 to request an interview; they will be contacted by telephone or email; and will have the option of allowing observations as well as an extension to the interview.

4. Justification / reasons for the changes

To have richer information on the learnings of the installers that are 'intermediaries' between the participants and the utility. This might help inform policy learnings for future rollouts of similar technologies.

5. Do the changes raise any ethical issues? Yes ☐ No ☒

If you answered 'YES', please identify these issues below:

6. Do the information sheet and/or consent form need to be changed? Yes ☐ No ☒

If you answered 'YES', please attach new information sheets and consent forms. Track changes must be used when making changes to previously approved documentation. Your amendment can not be assessed if Track Changes is not used.

7. Signatures:

Chief Investigator Name: Heather Lovell

Chief Investigator Signature:
Date:

Finance and Administration		
Fee Schedule as of 1 January 2017		
☒	Researchers affiliated with the University of Tasmania or the Department of Health and Human Services for the purposes of the research	No charge to the Researcher
☐	External Researchers	
	Amendment requiring Chair review	$150 (inc GST)
	Amendment requiring full Committee review	$360 (inc GST)
	Invoice Details	
	Name:	
	Organisation/University:	
	ABN Number:	
	Address:	
	Phone:	
	Please note: An administrative fee applies for the reissuing of invoices.	

ARENA CONSORT Smart Grid Pilot: Governance, implementation and the utility-community relationship.

This Information sheet is provided for you as a potential participant to keep, it explains the Bruny Island Smart Grid Pilot from the point of view of the PhD candidate's research.

Invitation

This PhD study is being conducted under the provisions of the Australian Renewable Energy Agency and the University of Tasmania. It is part of the larger CONSORT ARENA-ANU research Smart Grid pilot on Bruny Island.

Veryan Hann is a PhD Researcher in the School of Social Sciences and is part of the UTAS CONSORT Team, with her Supervisors who are also the key researchers on the social sciences aspect of this project; Associate Professor Heather Lovell, Dr. Phillipa Watson and Dr. Andrew Harwood. These questions are supplementary questions to those within the UTAS CONSORT requirements [H15886].

This study is being conducted in partial fulfillment of a PhD for Veryan Hann under the supervision of Associate Professor Heather Lovell, Associate Professor Kate Crowley and Dr. Phillipa Watson, and Dr. Andrew Harwood.

The research is federally funded by the Australian Renewable Energy Agency, in coordination with the University of Tasmania as a PhD studentship as part of a larger pilot study.

What is the purpose of this study?

The purpose of the ARENA CONSORT pilot and the PhD study is to test new energy technology on 40 households on Bruny Island as an isolated test bed. The 40 households will have solar PV and batteries connected with internet enabled software; these batteries then act as an 'intelligent grid', insofar as this pilot network reduces peak demand and load on the Bruny Island undersea cable, which is currently under pressure. As well as addressing the issue of peak demand by reducing pressure on the undersea cable, the study is designed to provide increased energy independence and energy cost savings to the householders.

The PhD study, broadly asks this same questions as CONSORT, through a social science and energy policy lens. The objective is to understand the relationship between the network, consumers that generate electricity and governance structures (including policy). To understand this is to understand the future of the grid: in terms of a trend; and the regulatory and social feasibility of governance and policy implementation consequences of smart grids. An initial hypothesis is that Smart Grids are a significant and emergent part of Australia's future energy system and that it is critical to understand consumer-utility-regulatory interactions in order to build policy which is fit for purpose into the future.

Why have I been invited to participate?

You have been asked to participate as you are either an installer or a renewable energy or energy policy expert that is not already being interviewed by the UTAS CONSORT Team for social science-based interviews. The interview with you is in addition to ARENA required interviews and forms part of the additional PhD research area.

Your participating in interview is voluntary, and there are no consequences if you decide not to participate in an interview. Your decision to participate in an interview (or not), will have no effect, for example, on your relationship with the University or any other party associated with this pilot research study.

What will I be asked to do?

Volunteers would be asked to participate in a phone interview by the PhD candidate, Veryan Hann. These questions are helpful for the PhD's area of interest of research.

In other cases, the PhD researcher is extending her research by interviewing some experts (installers/technical and policy experts for example), which explores additional questions or and different sectors that are not covered already in the pilot.

Volunteer participants and would be interviewed in relation to the Bruny Island project; as well as their unique and expert perspective in utility innovation and community involvement in supporting the network. Barriers and opportunities in terms of energy innovation, in relation to communities and innovation would also be explored.

The interviews would not be expected to exceed half an hour in length. Where it is not convenient to the interviewee to conduct the interview in person, the interview would be conducted via phone. Interviews would be expected to take place no earlier than October 2016. Veryan may also request a shorter follow up interview, nearing the end of the study for feedback and evaluation of the project from an implementation viewpoint.

It is expected that the telephone interview will be audio recorded – with the participant's permission. If the installer is happy for photos to be taken at Bruny Island, during the install process, but not identifying individuals then this would be done too.

The default setting is that interviewees would be de-identified. In the case that interviewees explicitly agree to having quotes attributing quotes to them, only on that basis would these quotes be identified within the PhD thesis.

Are there any possible benefits from participation in this study?

There are no foreseen direct benefits to the interviewees.

Are there any possible risks from participation in this study?
There are no foreseen direct, or calculable risks to the interviewees.

What if I change my mind during or after the study?
Participants are free to withdraw at any time, and that they can do so without providing an explanation. However, after the study has completed and the thesis has been written it will not be possible to redact quotes at that stage.

What will happen to the information when this study is over?
The raw data from all CONSORT and UTAS CONSORT UTAS interviewees will be kept for 7 years, or for three years after the completing of the project; whichever is the longest time. After this time, all data will be securely deleted from a UTAS password protected computer, and all hardcopy, paper files will be deleted. All data will be treated in a confidential manner.

How will the results of the study be published?
The researchers would plan to disseminate study findings through the writing of a PhD thesis; and also within reputable journals of international standing. The participants would not be identifiable within research published within journal articles, however, the participants may be identifiable within the PhD thesis on the condition that permission was granted by the interviewee for identification within the thesis.

What if I have questions about this study?
If there are questions about the study, the contact details for the researcher are as follows:

Veryan Hann, PhD researcher;

Under the governance of the ARENA/UTAS CONSORT Pilot;

With CONSORT UTAS main researcher contacts Dr. Phillipa Watson, Dr. Andrew Harwood, and led by Associate Professor Heather Lovell: Contact by phone: (03) 6226 7243.

Contact by email, PhD researcher (direct): veryan.hann@utas.edu.au

Also please note the following contact details for the Ethics Committee:

“This study has been approved by the Tasmanian Social Sciences Human Research Ethics Committee. If you have concerns or complaints about the conduct of this study, please contact the Executive Officer of the HREC (Tasmania) Network on +61 3 6226 6254 or email human.ethics@utas.edu.au. The Executive Officer is the person nominated to receive complaints from research participants. Please quote ethics reference number H16022.”

Participants may keep this information sheet, and you can consent to be involved through agreement on email response and/or by completing and returning the consent form.

ARENA CONSORT Smart Grid Pilot: Governance, implementation and the utility-community relationship.

Information sheet is for energy policy, regulatory and installer expert interviewees

1. I agree to take part in the research study named above.
2. I have read and understood the Information Sheet for this study.
3. The nature and possible effects of the study have been explained to me.
4. I understand that the study involves an interview of approximately half an hour, no video or audio recordings will be made, and a transcript of the key points within interview will be emailed to the participant for review, correction and amendment.
5. I understand that participation involves no foreseeable risks or hazards.
6. I understand that all research data will be securely stored on the researcher's University of Tasmania, password protected computer premises for five years from the publication of the study results, and will then be destroyed..

   Yes ☐ No ☐
7. Any questions that I have asked have been answered to my satisfaction.
8. I understand that the researcher(s) will maintain confidentiality and that any information I supply to the researcher(s) will be used only for the purposes of the research
9. I can choose to either agree to be identified or not identified as a participant in the publication of the study results within the PhD thesis. Any further publication through journals will only contain de-identified data.

   Yes ☐ No ☐
10. I understand that my participation is voluntary and that I may withdraw at any time without any effect.

    If I so wish, I may request that any data I have supplied be withdrawn from the research until 1 February 2019.

Participant's name: ____

Participant's signature: ____

Date: ________________________

Statement by Investigator

☐ I have explained the project and the implications of participation in it to this volunteer and I believe that the consent is informed and that he/she understands the implications of participation.

If the Investigator has not had an opportunity to talk to participants prior to them participating, the following must be ticked.

☐ The participant has received the Information Sheet where my details have been provided so participants have had the opportunity to contact me prior to consenting to participate in this project.

Investigator's name: ____

Investigator's signature: ____

Date: ________________________

ARENA CONSORT Smart Grid Pilot: Governance, implementation and the utility-community relationship.

Information sheet is for energy policy, regulatory and installer expert interviewees

1. I agree to take part in the research study named above.
2. I have read and understood the Information Sheet for this study.
3. The nature and possible effects of the study have been explained to me.
4. I understand that the study involves a telephone interview of approximately half an hour, and that additionally; I may be asked by the researcher to accompany me to undertake observations relating to the battery system installation process. I may choose to do only the telephone interview, the observations, or none at all.

   Permission for interview Yes ☐ No ☐

   Permission for observation Yes ☐ No ☐

   Permission for photographs Yes ☐ No ☐

5. I understand that participation involves no foreseeable risks or hazards.
6. I understand that all research data will be securely stored on the researcher's University of Tasmania, password protected computer premises for five years from the publication of the study results, and will then be destroyed..

   Yes ☐ No ☐

7. Any questions that I have asked have been answered to my satisfaction.
8. I understand that the researcher(s) will maintain confidentiality and that any information I supply to the researcher(s) will be used only for the purposes of the research
9. I can choose to either agree to be identified or not identified as a participant in the publication of the study results within the PhD thesis. Any further publication through journals will only contain de-identified data.

   Yes ☐ No ☐

10. I understand that my participation is voluntary and that I may withdraw at any time without any effect.

    If I so wish, I may request that any data I have supplied be withdrawn from the research until 1 February 2019.

Participant's name: ____

Participant's signature: ____

Date: ________________________

Statement by Investigator

☐ I have explained the project and the implications of participation in it to this volunteer and I believe that the consent is informed and that he/she understands the implications of participation.

If the Investigator has not had an opportunity to talk to participants prior to them participating, the following must be ticked.

☐ The participant has received the Information Sheet where my details have been provided so participants have had the opportunity to contact me prior to consenting to participate in this project.

Investigator's name: ____

Investigator's signature: ____

Date: ________________________

ARENA CONSORT Smart Grid Pilot: Governance, implementation and the utility-prosumer relationship.

This indicative question sheet provides a guide for PhD interviewees

Questions for energy policy expert [Tony Wood, 6th April 2017]

General (systemic) questions

1)From a system perspective, some may say that ideally we should we head to a **hybridized** system (centralized spine with decentralized adjunct components). Do you agree with this assessment?

(prompt – that centralized versus decentralized is a false dichotomy – that hydribridised is the future – which includes centralized for major industrials; hybridized CRE/EVs/batteries and off-grid for residential, and commercial sectors). Does that structure seem feasible?

2) It has been argued that **40% is the upper limit** for renewable energy penetration into the centralized grid (NEM) with its current technology and policy frameworks and incentives. Do you agree with this assessment?

(prompt - some engineers talk of work around technologies such as synthetic inertia and ancillary services that could fill a market niche in terms of stability; and batteries are seen as a solution for increasing stability with increasing SRE).

3) From the four energy **scenarios** from CSIRO's FutureGrid – is 'Rise of the prosumer' seen as most feasible? *(includes;Set and Forget; Leave the Grid; Renewables thrive)*

Battery-specific questions

4) As an example, if SA had a bunch of smartgrids or microgrids – pockets would get knocked down, but not the whole system – increasing **reliability** (with the PV+battery combo), do you agree this is the best way forward for SA?

5) In terms of **pricing and transparency** – for smartgrids – can it be cost-reflective and equitable? *(Cost-reflective if a technical reward may not be equitable – the Bruny phase 3 example, I think this might be a wicked problem on a small-scale)*

6)Policy people may suggest that there is a big regulatory gap between **ring-fencing rules and new battery technology**. Are there solutions here?

(prompt – ring-fencing is a disaggregating between retail/wholesale/distribution/generation assets to protect customers from unfair market advantage. If energy trading businesses (such as Reposit) are allowed to step in and trade behind the meter (in an unregulated space – could they negatively impact the customers because they don't get a choice when to trade- what if they create a virtual powerstation which games the system – creating mini-peak events to 'solve' and get paid for?

7) What do you see as the key ingredients to **support innovation** and **implementation** of smart grids – or will it happen in spite of policy (due to dropping costs)?

* * * * *

Notes to keep in mind from Pip 5th April: "Tony is knowledgeable enough to point out things in the questions he thinks are important to answer. You can let him know that you are interested in what he thinks is important about the topics you are asking about."

Journalist Peter Boyer's suggested question via email on 5th April:

"My main interest is in what the South Australian lesson can tell us about Tasmanian electricity supply and our island network's integration into the NEM; and more broadly, how SA's level of intermittent energy can be accommodated by the NEM, and what is the role a carbon price to the future of renewable energy."

Note: Version 4a = Regulatory and policy; version 4b = researchers; and version 4c = utility/network; version 4d = installers.

Household questions have been removed because these questions are captured already in detail under H15886.

ARENA CONSORT Smart Grid Pilot: Governance, implementation and the utility-prosumer relationship.

This indicative question sheet provides a guide for PhD interviewees

Questions for researchers, including CONSORT

[Interviewer comment – when interviewing interviewees outside CONSORT, compare the main similarities and differences in our pilots].

CONSORT researchers: In terms of this pilot being an innovative process, what do you see as the keys aspects to get right for your definition of success?

What do you see as barriers to transition to a new energy system?

How large a role do you see batteries playing in the future system?

How important do you think *coordination, integration and 'internal compliance'* is to this pilot's success and for social-technical innovation in general?

How important in your view, are these two aspects that shape innovation – market forces, evolving technology, and consumer demand [ecological or framework forces]; and directed government policy support for pilots such as this [SNM].

> How important do you think, is policy in supporting innovation?
>
> Do you think the above 'framework' forces be guided/supported?

ARENA CONSORT Smart Grid Pilot: Governance, implementation and the utility-community relationship.

This question sheet provides a guide for network and utility experts

Questions for the utility

Theme – Current interactions with consumers, the technology, and the future

Do you agree that if smart grids similar to the CONSORT project were deployed Australia-wide it would completely alter network and utility business models within the NEM?

If the CONSORT project is successful, are the winners equally the consumers and the network? The shift of participation and power to the consumers – is there a benefit of this to the network/utilities?

Is ring fencing and the 5 minute settlement the biggest barrier to regulatory equity for smart grids?

Do you see any barriers to consumers accepting this new technology?

Do you see any barriers to regulators, or other utilities around Australia accepting this new technology and change to the system?

Where do you see the future of the structure of the National Energy Market and the Australian grid if pilots such as at Bruny Island prove to implement successfully?

An international report in 2015 said that the major threat to utilities was non-utility players such as google and Telstra (virtual power stations) – do you agree? What do you see is the future for the network and utilities?

ARENA CONSORT Smart Grid Pilot: Governance, implementation and the utility-community relationship.

This question sheet provides a guide for installer expert interviewees.

Questions for Installers

Theme - Consumer, technology and utility interactions

Do you see any barriers to consumers accepting this new technology?

Do you perceive any tensions between the utility [or transmission, distribution business] and consumers?

If yes, do you think these are these more to do with feed-in-tariffs and reward structures, or more to do with the technology itself, or something else?

Are the customers happy – do they seem understand the technology, easily or with some difficulty?

Is explaining the technology easy or difficult?

Do you feel equipped/trained/supported to answer all the questions the participants pose?

How long does it take to explain so that they understand and accept the technology, less than half an hour, between 30mins-1hr, more. Do you feel you have the resources the participants/energy consumers require?

The installer plays an important role as an intermediary. This is the person that facilitated the flow of information and educates. What is the key thing to facilitate this?

Tasmania Explore the possibilities	HUMAN RESEARCH ETHICS COMMITTEE (TASMANIA) NETWORK	UTAS

SOCIAL SCIENCE HREC
FINAL REPORT FORM

For the period of: _______2018-2019_____________.

Important: Please send an electronic version of this report as a Word document to ss.ethics@utas.edu.au.
A signed copy of this form also needs to be forwarded electronically.

If you have any questions, please call: 6226 2975

1. Project Details	
Ethics Reference No.	H0016022
Project Title	ARENA CONSORT Smart Grid Pilot: Governance, implementation and the utility-prosumer relationship

2. Investigators	
A. Chief Investigator	
Name:	Professor Heather Lovell
Phone:	(03) 6226 7243
Email address:	heather.lovell@utas.edu.au
Contact address:	Social Sciences, Sandy Bay Campus, UTAS
B. Other Investigators **(If a student, please indicate his / her student status (Honours, PhD etc))**	
Name / status:	Veryan Hann (PhD Candidate)
Name / status:	Dr. Phillipa Watson – Researcher
Name / status:	Dr Andrew Harwood – Researcher
Name / status:	Dr Hedda Ransan-Cooper - Researcher

3. Status of Application		
Indicate which status applies to the project and include appropriate dates: The final data collection (final two stakeholder interviews) for H0016022 were conducted on 26/09/2018.		
Completed? ☒	Completion date: 26/09/2018	**Go to Section 4**
Abandoned? ☐	Date project abandoned:	**Go to Section 5**

4. Completed Projects
Please list the aims of the project that was originally approved: The PhD study examined the CONSORT electricity pilot; and the overall aim was to further the understanding of the dynamics between the network, householder and governance structures (including policy*)*. To understand this, infers a greater understanding of a future potential grid: i terms of trends, governance and policy and social feasibility of policy implementation of smart grids. The main thesis/project aim was to gain greater insight into the mechanisms for a deliberately accelerated socio-technical system transition.
Were these aims achieved? Yes ☒ No ☐ Please provide a brief explanation: A greater under standing the mechanisms for a deliberately accelerated socio-technical system transition was gained. This understanding was developed through - 1) engagement through the scholarship on socio-technical systems transition and policy implementation (2016 – 2019) 2) Observations and learnings from the CONSORT empirical case (2016-2019) 3) Interviews of policy and regulatory experts and battery system installers (2016 – 2018)

Please list any publications, conference papers, presentations, abstracts of theses etc. which have resulted from the study and attach copies to this report:

Conferences/presentations:

Panel presentation at Australian Utility Week, Melbourne, 22 November 2018. HUB 5 Digital Prosumer, speaking as part of a panel with Phillipa Watson (UTAS) and Archie Chapman (USyd).

Presented an original research paper at the international 4S conference, Sydney, August 2018. https://convention2.allacademic.com/one/ssss/4s18/index.php?cmd=Online+Program+View+Person&selected_people_id=9340946&PHPSESSID=49a2gqhp43kf1cimk7lt61osi3

Provided an original research presentation to NCCARF, UNSW, Sydney 2017 (previously reported Ethics)

Presented to Tasmanian Department of State Growth, Energy Policy Unit, 2017 (previously reporte to Ethics)

Presented ongoing PhD research to the biannual CONSORT project team meetings 2016-2018 (previously reported to Ethics)

Accepted/invited to the Energy Consumers Australia Foresighting Forum 2019 as a PhD/ERC Consumer Advocate, 20-21 Feb 2019, Sydney (attended but was not a speaker)

Accepted/invited to the International Sustainable Transitions conference (IST2019), 23rd-26th Jun 2019, Ottawa, Canada, with abstracts of contribution 1) "The identification of four pre-existing conditions for accelerating smart-battery deployment in a transitioning electricity sector in Australia" and 2) "Street-level bureaucrats beyond the frontier: The role of installers within a transitioning electricity grid." [invited but did not attend]

Accepted/invited to the 4th International Conference on Public Policy (ICPP4), 26th-29th June 2019, Montreal, Canada, with the abstract contribution ""The CONSORT residential battery trial: Challenges to implementation." within the panel "Policy Implementation Arrangements: Organizational, Structural and Managerial Aspects." [invited but did not attend]

Accepted/invited to the British Institute of Energy Economics conference 'Consumers at the Hear of the Energy System?' at the Blavatnik School of Government, Oxford, September 18-19, 2018. The accepted abstract was titled "The Bruny Island Smart-grid Pilot: How much agency is desirable for the prosumers; and how much is manageable for the networks?" [invited but did no attend]

Publications

Hann, V. (2018). 'Consumers Drive Technological Change Within Energy System Transitions' IEEE Future Directions, Technology Policy & Ethics, September Issue 2018. http://sites.ieee.org/futuredirections/tech-policy-ethics/september-2018/consumers-drive-technological-change-within-energy-system-transitions/ (previously reported to Ethics)

Ransan-Cooper, H., Chapman, A., Scott, P., Hann, V. (2018). 'Tesla's 'virtual power plant' might be second-best to real people power.' The Conversation, Australia. 19 Feb 2018, https://theconversation.com/teslas-virtual-power-plant-might-be-second-best-to-real-people-power-90319 (previously provided to Ethics)

Lovell, H., Hann, V., and Watson, P. (2017). 'Rural laboratories and experiment at the fringes: A case study of a smart grid on Bruny Island, Australia.' Energy Research and Social Science (ERSS Oct 2017, https://doi.org/10.1016/j.erss.2017.09.031 (previously reported to Ethics)

Contributed to the interim ARENA milestone reports, producing a PhD report on progress that formed an appendix on two reports (2017-2018) (previously reported to Ethics)
Contributed to CONSORT ARENA interim milestone reports (2017-2018) with a PhD report of research progress as an appendix within a 2018 interim project report. (previously reported to Ethic
Contributed to CONSORT Social Science Final Report – Watson et al (2019)
http://brunybatterytrial.org/wp-content/uploads/2019/05/consort_social_science.pdf

Go to Section 6

5. Abandoned Projects

Did the project commence? Yes ☐ No ☐

Why was the project abandoned? Please provide brief details, including whether the abandonment created any ethical issues. If so, how they were resolved.
Describe any data that was collected and indicate how it has been stored and / or destroyed.
If any publications have resulted from this project, please list any publications, conference papers, presentations, abstracts of theses etc. and attach copies to this report:

Go to Section 6

6. Data Storage

For completed and abandoned projects, if applicable, please state how and where your data is being stored, and for how long it will be retained. Address any issues of data security.
Please note: Data must be stored for at least five years beyond the date of publication and then destroyed. All data must eventually be destroyed unless explicit consent is obtained from the participants to archive their data.
……………………………………………………………………………………………………..

The interview data (2016 – 2018) is be kept on a password protected, University of Tasmania computer in possession of the PhD candidate. The raw data for the CONSORT project is kept on UTAS computer and UTAS server (N Drive) on campus, and in a locked room if the room is unoccupied for any length of time. For the PhD student under the CONSORT umbrella, PhD related interviews with installers or energy policy experts and so forth will also be on a UTAS password protected computer and is also backed up on the UTAS server (N drive) and the door to the office is locked when unattended for any length of time.
How and when will the data be destroyed?
The information will be kept for 5 years after the completion of the pilot project, then deleted securely, with any paper data shredded.

7. Ethical Issues

Please answer YES or NO to the following questions. If you answer YES to any question, give details below. Please attach a separate sheet if there is insufficient space.	Yes	No
Did any participants withdraw from the project during this year? *If yes,* please provide details. One householder moved to a new house and so was no longer part of the Trial	☒	☐
Did any ethical issues arise during the research? *If yes,* provide details, including whether or not they were foreseen, and how they were resolved. ………………………………………………………………………………………	☐	☒
Have any participants suffered harm or adverse effects? *If yes*, has this been reported to the committee? If not, please explain why and append the reports. ……………………………………………………………………………………..	☐	☒
Have any complaints been received regarding the project? *If yes,* please provide details of the complaint, and how it has been resolved. ……………………………………………………………………………………..	☐	☒
Have you departed at all from the approved protocol? *If yes,* please provide details. …………………………………………………………………………………..	☐	☒
Has there been any breach of confidentiality of data, which includes identifying information? *If yes,* please provide details, including what has been done to remedy the breach. ………………………………………………………………………………………	☐	☒

8. Statement by Chief Investigator
I accept that the information provided in this report is a true record of the research undertaken by myself, or the students under my supervision: **Chief Investigator name: Heather Lovell** **Chief Investigator signature:** **Date: 6th August 2019**

Interview data

Interview data for the PhD thesis				
Name of interviewee	**Expertise/ Organisation/ state**	**Date of interview/ telephone or in-person**	**Chapter used in**	**PhD-specific / CONSORT team interview/ interviewer/code**
CONSORT interviews as part of the social science team				
CONSORT household participants (coded)	Householders/TAS Pre-installation phone interviews	Nov 2016 to Mar 2018/telephone	Various [empirical chapters	As part of CONSORT SS team -BT101 – BT141
CONSORT household participants (coded)	Householders/TAS Post-installation visits	July 2017-Jan 2018/in-person	Various [empirical chapters	As part of CONSORT SS team -BT101 – BT141
Focus Group	Focus group and information night with all participants invited	22 Sep 2016/in-person	General background	As part of CONSORT SS team
Research partner interviews (internal to the CONSORT pilot), names removed				
Innovation engineer, TasNetworks/TAS		25 Aug 2017; 29 Aug-2017; 14 Feb 2018/ telephone	Ch5; Ch6; Ch7	PhD-specific
Smart grid research fellow(economics)/ USYD/NSW		12 Dec 2016/telephone 22 June 2017/telephone	Ch7	PhD-specific

Customer engagement specialist, TasNetworks/TAS		4 May 2017/telephone 23 May 2017/telephone	Ch1; Ch4 [for ERSS paper]	For ERSS paper (social science team)
Reposit Power Manager/telephone		22 Feb 2018/telephone	Various [empirical chapters]	PhD-specific
Reposit Power Director		2-Mar-2018/telephone	Various [empirical chapters]	PhD-specific
CONSORT Research Leader/ANU		26-Sept-2018/telephone	Ch4	PhD-specific
Innovation Team Leader/TasNetworks		10-Oct-2018/telephone	Ch4	PhD-specific
Social Science Lead/UTAS		9-Oct-2018/telephone	Ch4	PhD-specific
Power systems engineer, UTAS and researcher on CONSORT		26 Sept 2017 in-person 1 Aug 2018/in-person	General/context and Ch7	PhD-specific
Installer interviews (internal to the CONSORT pilot)				
Installer A	GM of Installer business/Coded/TAS	4 Dec 2017/telephone	Ch6	PhD-specific
Installer B	GM of Installer business/Coded/TAS	29 Nov 2017/telephone	Ch6	PhD-specific
Installer C	GM of Installer business/Coded/TAS	28 Nov 2017/telephone	Ch6	PhD-specific
Installers C, D	Electricians shadowed to the island	24 April 2018/ in-person	Ch6	PhD-specific

Governance and policy interviews (external to the pilot)				
Scott, John	Retired advisor to government/ACT	23 Apr 2018/telephone	Ch1; Ch5	PhD-specific
Leitch, David	Energy Utility economist/consultant/NSW	12 Sep 2017/telephone	Ch7	PhD-specific
Wood, Tony	Energy Program Director, Grattan Institute/VIC	6 Apr 2017/telephone	General	PhD-specific
Gilding, Jack	EO, Tasmanian Renewable Energy Alliance/TAS	13 Sep 2017/in-person	Ch7; (Ch5 to a lesser extent)	PhD-specific
Anonymised	Retired policy advisor in NSW/TAS governments	16 Sep 2017/telephone	Ch1; Ch5	PhD-specific
Other residential battery trial interviews				
Newman, Andrew	Strategy Officer, Strategy and Knowledge Sharing, ARENA	24 and 25 Jan 2017/ telephone	Ch1, Ch4	PhD-specific
Swinson, Vanessa; Hamer, Joanne	Energex – Energex battery trials (Demand Management Team)	13 June 2017/ Telephone conference call	Ch4; Ch5, Ch8	PhD-specific

Stiebel, Lisa	Program coordinator, SERREE Project - Ginninderry Consumer Attitudes Study.	10 Feb 2017/telephone	Ch1; Ch4; Ch8	PhD-specific
Cox, Jason.	Program Coordinator, Moreland Microgrid. Moreland Energy Foundation [virtual trial]	7 Feb 2017/telephone	Ch1; Ch4; Ch8	PhD-specific
Interviews for systems-context				
Negnevitsky, Michael	Power systems engineer, UTAS	9 May 2017/ in-person	General/context	PhD-specific
Jones, Laura	Innovation engineer, TasNetworks, CONSORT *	17 Jan 2017/telephone	ERSS paper*	SS team
Bevan, Richard	Former CEO Transend	20 Apr 2017/in-person	General/context	PhD-specific
*The 'ERSS paper' was a paper which this author contributed to as a co-author in the journal *Energy Research and Social Science*				

[extracted: Table 3.3, Chapter Three]

List of internal project documents, internal communications and external project documents for the CONSORT pilot

Internal project documents

CONSORT. (2015a). CONSORT: Consumer Energy Systems Providing Cost Effective Grid Support. *Project Plan*. Australian National University, TasNetworks, Reposit Power, University of Sydney, University of Tasmania.

CONSORT. (2015b). *Knowledge Sharing Plan;* CONSORT - Consumer Energy Systems Providing Cost-Effective Grid Support [Unpublished, Internal document]. Agreement document for knowledge sharing ARENA, ANU and CONSORT partners. Canberra.

CONSORT. (2015c). Research and Development Program R&D *Project Application - Stage 2.* Project No 2015/RND006; ST001. R&D project application. Australian National University. Canberra.

CONSORT. (2015d). *Response to ARENA's Feedback* [Unpublished, Internal document] Canberra, Australian National University.

CONSORT. (2017). *Trial plan for coordinated battery operations* [Unpublished, Internal document]. In E. Franklin, P. Watson, A. Fraser, G. Verbic, & A. Reid (Eds.), CONSORT Trial Committee: ARENA, archival.

TasNetworks. (2016). Bruny Island Battery Trial: *Customer Engagement Plan* (Community Consultation Plan).

Reports and media publicly available

ANU. (2018). Bruny Island battery trial wins Engineering Excellence Award. Engineers Australia Tasmanian Engineering Excellence Award (AEEA). [Press release]. Retrieved from https://cecs.anu.edu.au/news/bruny-island-battery-trial-wins-engineering-excellence-award

ARENA. (2018b). CONSORT Bruny Island Battery Trial recognised at Clean Energy Summit [Press release]. https://arena.gov.au/blog/consort-bruny-island-battery-trial-recognised-at-clean-energy-summit/

CEC. (2018). Clean Energy Council Awards: 2018. Business Community Engagement Award winner - TasNetworks. [Press release]. Retrieved from http://www.cleanenergysummit.com.au/awards.html

CONSORT. (2018a). *CONSORT Project Milestone 5: April -September 2018. Lessons Learnt.* Canberra: ARENA. https://arena.gov.au/assets/2018/10/ANU-CONSORT-Project-Update-3.pdf

Lovell, H., Hann, V., & Watson, P. (2018). Rural laboratories and experiment at the fringes: case study of a smart grid on Bruny Island, Australia. Energy Research & Social Science, Volume 36(146-155). doi:doi.org/10.1016/j.erss.2017.09.031

Jones, L., Franklin, E., Fraser, A., & Reid, A. (2019). *Project Final Report: Lessons Learnt During Trial Deployment.* CONSORT: "Consumer Energy Systems Providing Cost--Effective Grid Support" Retrieved from http://brunybatterytrial.org

Ransan-Cooper, H., Chapman, A., Scott, P., & Hann, V. (2018, 19 Feb 2018). Tesla's 'virtual power plant' might be second-best to real people power. The Conversation. Retrieved from https://theconversation.com/teslas-virtual-power-plant-might-be-second-best-to-real-people-power-90319

Watson, P., Lovell, H., Ransan-Cooper, H., Hann, V., & Harwood, A. (2019). *Project Final Report: Social Science.* Retrieved from http://brunybatterytrial.org/wp-content/uploads/2019/05/consort_social_science.pdf

Internal data, communications and interviews

BT128. (2018). BT128 post-install interview transcript. In Interviewed by UTAS Social Science Researchers (Ed.).

CONSORT Research Lead. (2018, 26 Sept 2018) ANU - CONSORT Project Genesis through the lens of SNM. Interview with Professor Sylvie Thiebaux,/Interviewer: V. Hann. Unpublished researchers transcript.

CONSORT Social Science Lead. (2018, 9 Oct 2018) UTAS Social Science perspective - CONSORT Project Genesis through the lens of SNM. Interview with Professor Heather Lovell./Interviewer: V. Hann. Unpublished researcher notes.

Cox, J. (2017, 7 Feb 2017) PhD interview with Jason Cox, Program Coordinator, Moreland Microgrid Investigation/Interviewer: V. Hann. Unpublished researcher's transcript.

Jones, L. (2017, 27-29 August 2017). [Discussion with TasNetworks Utility Innovation Engineer about reliability and battery state of charge: by emails and telephone.

Newman, A. (2017, 30 Jan 2017) ARENA Strategy Officer, Energy Networks Australia Stocktake and ARENA projects with social science analysis./Interviewer: V. Hann. unpublished researcher's transcript, University of Tasmania.

Social Researcher. (2016). Pre-installation focus group schedule - Bruny Island Battery Trial [Unpublished internal data]. In.

Social Researcher. (2018a). Biannual CONvention Canberra meeting 10 April 2018 [Unpublished internal communications]. In.

Social Researcher (2018b, 27 Feb 2018). [Pre-installation interview delays: Email 'Battery Trial Social Research' [Unpublished internal communications].

Social Researcher. (2018c). UTAS Social Science BiCon presentation 17 Oct 2018 [Unpublished internal communications]. In Biannual Convention.

Stiebel, L. (2017, 10 Feb 2017) PhD interview with Lisa Stiebel, project manager of SERREE project- Ginninderry Consumer Attitudes Study./Interviewer: V. Hann. Unpublished researcher's transcipt.

Swinson, V., & Hamer, J. (2018) ENERGEX Residential Battery Trial, PhD interview. /Interviewer: V. Hann. Unpublished researcher's transcript.

TasNetworks Customer Engagement Advisor. (2017, 23 May 2017) PhD interview with Shannon Stennings. Themes relating to customer engagement; customer-technology interface, and acceptance./Interviewer: V. Hann. Unpublished researcher's transcript.

TasNetworks Innovation Team Leader. (2018, 10 Oct 2018) TasNetworks - PhD interview, Project genesis and SNM in CONSORT. Andrew Frazer, Team Leader, Innovation Engineer./Interviewer: V. Hann. Unpublished researcher notes.

UTAS Social Science Team. (2019). CONSORT Participants 20180924. Excel Spreadsheet - Raw unpublished data. UTAS.

Appendix B — Candidature outputs, presentations, publications and PhD contribution to ARENA Milestone Reports

Summary of outputs during Candidature

Conferences/presentations:

- Panel presentation at Australian Utility Week, Sydney, October 2018.
- Presented an original research paper at the international 4S conference, Sydney, August 2018.
- Provided an original research presentation to NCCARF, UNSW, Sydney 2017
- Presented to Tasmanian Department of State Growth, Energy Policy Unit, 2017
- Presented ongoing PhD research to the biannual CONSORT project team meetings 2016-2018
- Accepted/invited to the British Institute of Energy Economics conference 'Consumers at the Heart of the Energy System?' at the Blavatnik School of Government, Oxford, September 18-19, 2018. The accepted abstract was titled "The Bruny Island Smart-grid Pilot: How much agency is desirable for the prosumers; and how much is manageable for the networks?" [invited but did not attend]
- Accepted/invited to the Energy Consumers Australia Foresighting Forum 2019 as a PhD/ERC Consumer Advocate, 20-21 Feb, 2019, Sydney
- Accepted/invited to the International Sustainable Transitions conference (IST2019), 23rd-26th June 2019, Ottawa, Canada, with abstracts of contribution 1) "The identification of four pre-existing conditions for accelerating smart-battery deployment in a transitioning electricity sector in Australia" and 2) "Street-level bureaucrats beyond the frontier: The role of installers within a transitioning electricity grid." [invited though did not attend]
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Publications

- Global Status Report for Renewable Energy, REN21 Lead Country Contributor (Hann, Australia) GSR 2016, GSR2017, GRS2018 – policy contribution

[acknowledged under Lead Country Contributors: Australia, p.11 GSR2018 report]

- Special report 1.5 Degrees (WG1) – 2018 Expert reviewer –voluntary policy contribution [acknowledged p.7 of report Annex]
- Crowley, K., Hann, V., Nakamura, A. (2018) 'Designing a Community Renewable Energy (CRE) Strategy', Environmental Management, 54, (11) pp. 67-71. ISSN 1340-2552 [A1 Refereed Article; Japanese]
- Hann, V. (2018). 'Consumers Drive Technological Change Within Energy System Transitions' IEEE Future Directions, Technology Policy & Ethics, September Issue 2018.http://sites.ieee.org/futuredirections/tech-policy-ethics/september-2018/consumers-drive-technological-change-within-energy-system-transitions/
- Ransan-Cooper, H., Chapman, A., Scott, P., Hann, V. (2018). 'Tesla's 'virtual power plant' might be second-best to real people power.' The Conversation, Australia. 19 Feb 2018, https://theconversation.com/teslas-virtual-power-plant-might-be-second-best-to-real-people-power-90319
- Lovell, H., Hann, V., and Watson, P. (2017). 'Rural laboratories and experiment at the fringes: A case study of a smart grid on Bruny Island, Australia.' Energy Research and Social Science (ERSS), Oct 2017, DOI. 10.1016/j.erss2017.09.031
- Contributed to the interim ARENA milestone reports, producing a PhD report on progress that formed an appendix on two reports (2017-2018)
- Contributed to CONSORT ARENA interim milestone reports (2017-2018) with a PhD report of research progress as an appendix within a 2018 interim project report.
- Contributed to CONSORT Social Science Final Report – Watson et al (2019) - http://brunybatterytrial.org/wp-content/uploads/2019/05/consort_social_science.pdf

The remainder of this appendix comprises:

1) **PhD-specific contributions to ARENA Milestone Reports**
    - ARENA Milestone 2 Interim Report March 2017
    - ARENA Milestone 4 Interim Report March 2018
2) **Example publication**
    - IEEE newsletter 19 September 2018

PhD-specific Contribution to ARENA Milestone Reports

PhD report for the ARENA CONSORT Milestone 2 Interim Report, March 2017

The UTAS CONSORT PhD Candidate has supported the UTAS team by conducting fieldwork; interacting with the whole of CONSORT as required (telecons, bi-annual meetings, drafts of work and collaboration as requested). Additionally, beginning additional 'PhD extended' interviews; helping keep database activities up to date and submitting literature reviews on governance, a specialised type of project management (strategic niche management), and large technical systems theory and innovation in the 6 months to the March 2017 Milestone 2 report.

Between September 2016 and February 2017 UTAS PhD has undertaken or completed these social research activities:

- Supported fieldwork activities including attending forums; focus groups; contribution to interview schedule; and conducting and recording householder interviews; 25 are now complete [28-02-2017]
- Supported UTAS internal database management- for data gathering and timing, and data/process gap-analysis.
- Additional fieldwork for PhD related questions that extend beyond CONSORT requirements that support deeper theory development - started on 17th Jan 2017. Interview with utility; and two other ARENA projects (one was a microgrid investigation);
- Engagement - high-level or PhD-specific knowledge sharing activities:
    - Conference presentation at the National Climate Change Adaption Research Facility (NCCARF) in Sydney 21st Feb 2017. This presentation is tangential to the PhD research (due to IP and confidentiality uncertainty

and prior to public launch of CONSORT – a book of proceedings is published by NCCARF) however, it is topical. Title: *Bruny Island Smart Grid Pilot: Beating the Utility Death Spiral with Distributed Storage.*

    - Provided a talk to the Tasmanian Department of State Growth (Energy Policy unit) 25th Jan 2017. Title: *Consumer energy systems providing cost-effective grid support: Social Research - Bruny Island Battery Trial.*

- Conducted international reviews of the literature in four fields;
    - Sociotechnical systems transition theory;
    - Policy implementation theory;
    - Network governance and,
    - Strategic niche management theory.

Current UTAS PhD social research activities:

- Has started extended interview types (3 so far, utility and 2 other ARENA projects)
- Preparation for UTAS internal requirements - Confirmation of Candidature in June – literature review drafting and report
- Conducting final pre-installation interviews with Dr Phillipa Watson
- Contributing to journal article [Special Issue] with PhD supervisors A/P Lovell, and Dr Watson

Social research activities to be conducted the UTAS PhD in the next 6 months:

- Conduct post-install, face-to-face interviews with participants on Bruny Island as part of the UTAS research team
- Complete the Confirmation of Candidature (CoC) as part of internal UTAS requirements
- Finalise academic literature review, synthesis of cross-disciplinary theory
- Conduct ‘extending’ (CONSORT plus PhD) interviews with regulatory and policy experts to build on theory and case study of Bruny Island
- Support and conduct UTAS preliminary thematic analysis of data from pre and post install interviews

Aims, methodology, indicative interview questions from approved PhD Ethics H16022

The premise of the PhD study is that Smart Grids are a significant and emergent part of Australia's future energy system and that it is critical to understand consumer-utility-regulatory interactions in order to build policy that is fit for purpose into the future.

In brief - PhD Aims, and outline of proposal: The PhD study will examine the CONSORT electricity pilot; and the overall aim is to further the understanding of the dynamics between the network, householder and governance structures, including policy. To understand this, is to understand the future of the grid: in terms of trends, and the regulatory and social feasibility of policy implementation of smart grids.

Literature areas (for application to the Bruny Island pilot):

Socio-technical transformation and systems innovation

The Bruny Island Smart Grid pilot can be conceptualised as a micro- socio-technical system, which is testing new technology interfaces. The Socio-technical system consists of networks of actors (firms, individuals and other collective actors); technical and societal norms and 'material artefacts and knowledge' (p.956), whereby the 'different elements of the system interact, and together they provide specific services for society' (Markard et al, 2012, p.956).

Implementation Literature

CONSORT is a form of experimental implementation / experimental governance and administrative Implementation. The CONSORT pilot provides 'a study of contingencies' - something that many theorists agree is the main way forward for successful implementation. Implementation theory is a largely 'forgotten part of the policy cycle, left to administrators' – and I argue it should not be forgotten for the pilot in terms of transferable learning.

Literature on a synthesis of Strategic Niche Management and Network Governance theories and their relevance to the Bruny Island case study

The Bruny Island battery trial is a testbed, that arguably, will demonstrate a small part of a society-based technical transition; the trial is possibly an ‘early indicator’ of structural change that is occurring throughout the Australian electricity system - and so literature chosen reflects ideas on innovation and transition; on managing change; and on the role of governance. In both streams of theory, it is found that **innovation is supported by tolerating (initial) inefficiencies** that would not be accepted in the real world (Hermans et al, 2013); and that this is where learning occurs.

The basis is that all the technical components of the system are already known; i.e. the battery technology, the PV technology, the internet and computing technology, the electrical engineering – none of these elements are unknown or untested (in isolation as components). It is only the interaction and coordination between the components – their internal compliance; and the testing between people and the integrated system. In this sense, the **sociotechnical integration and is novel**, and untested.

One of the most important applications to the battery storage pilot on Bruny Island is the finding that **residential-scale behaviour change** may encourage niche development and growth. Behaviour change as leading a transition is a critical but under-documented aspect that lies within the theory. This type of governance relating to behaviour change could also be called citizen-centric policy implementation. Behaviour change is seen as an end result of policy, rather than a part of learning and **experimental policy implementation**.

PHD REPORT FOR THE ARENA CONSORT MILESTONE 4 INTERIM REPORT, MARCH 2018

February 2017 — February 2018

1 Fieldwork

CONSORT fieldwork

'Extending' PhD-specific fieldwork

2 Academic and PhD related activities

3 Team contribution and collaboration

4 Research activities to be conducted the UTAS PhD in the next 12 months:

1 Fieldwork

CONSORT fieldwork

- Pre-install telephone interviews of pilot participants (householders)
- Post-install on-site interviews of pilot participants (householders)
  - *a range of themes arising from the post-install interviews which shaped the direction of the 'extending' fieldwork below:*

'Extending' PhD-specific fieldwork

- Interviews of the TasNetworks innovation engineer on the CONSORT project (3 interviews, 2 of which were audio recorded). - *This was for a paper on the installers; this engineer was also interviewed for perspective on a residential cost-benefit analysis chapter*

- Interview of well-known policy expert Tony Wood of the *Grattan Institute - Contextual, and broad policy*
- Interview of other researchers within other disciplines on CONSORT, namely Dr Archie Chapman, smartgrid economist, USYD; Dr Evan Franklin, power systems engineer, UTAS, formerly USYD. *- Both were interviewed for a householder/residential cost-benefit analysis paper*
- Interviews of 3 battery system installers that were working on the trial – *They were interviewed for a chapter on installers, which demonstrates the critical nature of the installers for facilitating or thwarting acceptance of new a technology*
- Interview with well-known utility economist and *reneweconomy* author David Leitch - *This interview was for the cost-benefit analysis paper*
- Interview with solar advocate and community energy educator, Jack Gilding – *This interview was for incommensurables, including reliability and backup, in the cost-benefit analysis paper*
- Interview of Ricard Bevan, former *Transend* CEO and power systems engineer – *Interviewed on technical aspects of the residential cost-benefit analysis paper*

2 Academic and PhD related activities

- Drafted 3 PhD chapters over the last 12 months — the first two are to be pitched to journals and written as articles to a scholarly standard for publication and acceptance at an international level:
  - Cost-benefit analysis -
    Title: “Cost Benefit Analysis on Battery Storage Systems”
  - Intermediaries, or installers -

Title: “Household Energy Storage Revolution: Agents of Change - The Influence of Intermediaries in Catalysing Transition”

  - Methodology (not for publication) -
    Title: “Methodology”
  - Literature review (written prior to February 2017, and not for publication, but will be drawing on for the findings)

- PhD Confirmation of Candidature, complete June 2017
- Co-authored in the *Energy Research and Social Science* international journal with supervisors A/P Lovell, and Dr Watson, published in January 2018.
- All 4 PhD units completed by February 2018
  - Completed the elective unit *Qualitative Research Methods* in December 2017
  - Completed the elective unit *Effective Speaking* in February 2018
- Lead country contributor (Australia) for the *Global Status Report on Renewable Energy* (GSR2017, GSR2018), for REN21, the *Renewable Energy Policy Network for the 21st Century,* under the *United Nations Environment Program*
- Expert Reviewer for the *IPCC Special Report on 1.5 Degrees*, for the first and second order drafts, December 2017 to February 2018
- UTAS Human Ethics annual review (submitted late 2017), and an amendment to include expansion on installers. Additional amendment in early 2018, submitted 27 Feb 2018, adding Dr Andrew Harwood as a co-investigator on the PhD Ethics, H0016022
- Dr Andrew Harwood joining the PhD supervisory team in July 2017, and I will continue in a 4-team member supervisory team until the completion of the PhD in 2019

3 Team contribution and collaboration

- Contributed to the UTAS team through the design phase of the post-install interviews based on the initial topic map
- Contributed to the UTAS-ANU team meetings, with particular emphasis on fieldwork feedback, research analysis and potential project risks, and logistics and planning
- Contributed to the CONSORT Biannual Convention through sharing of learnings and activities with the wider team (all CONSORT PhDs across disciplines shared in this way)
- Collaborated with the wider CONSORT team as required, including an article published in *The Conversation*, February 2018 as fulfilling an ARENA knowledge sharing milestone

4 Research activities to be conducted the UTAS PhD in the next 12 months:

- Finalise all interviews and fieldwork
- Finalise analysis and writing of papers
- Continue knowledge sharing re ARENA— for example, an international conference in Sydney with PhD co-supervisors A/P Heather Lovell and Dr Andrew Harwood in August 2018
- Pitch papers to international journals, co-author with co-supervisors, under the Vancouver Protocol
- Complete a full draft of PhD thesis by March 2019

Consumers Drive Technological Change Within Energy System Transitions

By Veryan Hann

September 2018

Introduction

Energy systems in OECD countries are transitioning towards decentralization. This shift is due to energy policy and climate policy pressures, changing consumer preferences, and drive to decentralized generation and storage, and this transformation is also driven by technological advances such as the 'internet of energy' of which includes smart grids. This article offers an insight into this socio-technical change from a sociological perspective; the challenges for policy makers, and the challenges for energy networks, through the lens of an Australian smart grid pilot.

Australia serves as an interesting case study in relation to energy system transformation. Australia has one of the highest per capita residential solar PV installations in the world; a population under 25M with a current installed capacity of 7.8 GW [1]. Residential battery storage is poised to accelerate deployment in Australia and around the world due to rapidly reducing battery prices [2]. However, the full social, governance and equity implications of this rapidly changing electricity system is not yet known by governments and utilities alike.

Technological change heralds complex social implications; and included among them — issues relating to energy equity; emergent businesses within the energy sector; issues of data privacy; and of increased consumer participation in a distributed energy market. Until now, the management of electricity, from an economic and policy perspective, was as a *public good* regardless of the type of utility; however, with storage behind the meter, this public good is now treated as a *private good* and this raises complex governance and policy issues.

Well-considered energy policy is now required to help shape the technological future of energy systems. In a wider view, we can see that the current energy system transformation is an evolving 'conversation' between the social and the technical — because after all, we shape our technology, just as our technology shapes the way we live and work. From a social perspective, the existence of technology can be either good, or bad, or neutral [3]. *Technology policy is therefore a key tool required for shaping the direction of technology for the social and public good.*

The electricity system is a socio-technical system under transition

The electricity system is a *socio-technical* system as it inherently holds both social and technical attributes [4]. People, as energy consumers could be described as a number one *non-technical issue* for rolling out new technologies, and we may be reminded by Thomas Hughes' 1983 seminal book *Networks of Power Electrification in Western Society 1880-1930* that technology's purpose is to *serve society.* Technology is not a stand-alone problem to solve, and technological progress is not separate from the shaping influences of politics, economics, science, people and policy. To understand these influences at a meta-level, Hughes describes 'systems thinking' and he argued that in the late 1880's

Thomas Edison possessed 'systems-level thinking,' and this determined successful deployment of new technologies. Systems thinking is beyond perfecting components, but working at a higher, *systemic* level which shapes technological progress [4,5].

Placing people centrally, rather than technology, in a large-scale socio-technical change is indeed a paradigm shift. The utility and energy network paradigm shift has been marked in recent years in Australian federal-level strategic reports [6], [7] in placing *customers 'at the centre' of the energy transition.*

In terms of large-scale **change system change**, and using the example of residential batteries, a systems-thinking approach might be exampled by Elon Musk's *Tesla* batteries, simply because all the components are housed within the one system, which reduces overall complexity [8]. **Telsa**, as a 'plug and play' reduces complexity and choice for the consumer and the installer. Consumers are driving change, so this reduced complexity as opposed to purchasing inverters and battery management system software separately could have a significant business advantage at a system-wide level. However, the market has significant competition and emergent businesses in the battery installation space, and I suggest that businesses that invest in a 'whole solution' will be ahead of the market. Questions remain — We might look to consumers as the main driver of change and ask; Will consumers willingly absorb additional complexity? Might they rather outsource the complexity to emergent players such as ICT companies? Do consumers really want increased agency, or is it an abstract desire, that once realised is a burden? Is cost a greater driver? Tailored and customized home energy solutions will come at a price, both in terms of time to understand and to manage. If consumers have a sense of trust they will trade their active participation in the energy market for simplicity — and new emergent businesses will fill that space. Emergent demand-side management ICT players will provide the service of reducing the complexity of some energy management systems. They will do this with a systems-thinking approach.

Case Study – CONSORT Smart Grid

An Australian smart grid is being trialed through a 34-household smart-grid pilot, known as CONSORT: *CONSumer energy systems providing cost-effective grid support*, funded by ARENA *The Australian Renewable Energy Agency* [9]. CONSORT is a multi-disciplinary partnership of industry and academia — comprising computer scientists from the Australian National University; economists from the University of Sydney; social scientists and policy academics from the University of Tasmania; as well as a 'new entrant' ICT software start-up; and an incumbent network utility. Located on Bruny Island, Tasmania, CONSORT specifically trials the consumer acceptance, economics, and technical feasibility of employing the batteries as individually responding within a virtual power plant [10]. This consumer-enabled support on the island's constrained undersea cable is recognized as a service; and the network pays the consumers for the service as it off-sets costly diesel generator use in times of peak demand.

Social science issues are researched in this pilot in terms of deployment success predictors.

The social science factors such as consumer acceptance are demonstrably as important as technical competence in R&D projects for technical deployment success. However, the Bruny pilot is the only ARENA project of 200 past and present projects with a dedicated social science team on a technical pilot or 'real world' roll-out. However, technical success of a roll-out may not indicate acceptance; in the past impressive technical and economic feasibility has not necessarily lead to the adoption of a new technology by consumers [11].

The social science (energy policy) PhD on the project observed that coordination of problem-solving between project partners was key — project partners communicated closely in an inter-disciplinary team to solve problems; this provided a bird's-eye view of the project as a whole. As a team project it provided the systems-thinking perspective. In addition, technical integration and intra-project policy was important. Internal policy was important for consistency and coordination between research partners; and technical integration was important for the system to work — for example, software from the battery management system was adapted so that it would communicate to various brands of inverters, and would override those inverters settings when necessary for the project and the network requirements.

Communication and education with consumers is a key for acceptance, trust, and deployment success. Furthermore, these keys are argued to be principles applicable to other socio-technological pilots, not just smart grids, however policy and regulatory support is required.

Conclusion

Technology and policy are interrelated; consumers are central to technology change and social implications have equal impact for deployment success as technological success. Policy can indeed be both supportive of innovation, and be technology-neutral, but it does require regulatory support. The new energy future requires a clear formulation of possible strategies clearly for policy makers to make decisions. We should aspire to encourage an agreed vision, discussion, networking and knowledge transfer between government and non-government bodies. This level of coordination can be described as a systems-thinking approach.

At a high-level, these questions are governance-related where solutions to policy issues are actor-neutral. The range of actors that should be expected to participate in policy discussion include government itself to incumbent utilities new entrants; and consumer advocacy coalitions. These learnings also relate to wider governance aspects of distributed storage, and other distributed technologies, which currently remains an unsolved key for future policy researchers.

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